marine shells to form layers of limestone. (**Lot 35) Atrypa hystrix, Spirifer disjunctus,** crinoid stems, bryozoa, etc...........................1700

Portage Series (2410′)

31. Sandstone and shale; grayish-green to grayish-brown, fine-grained, platy sandstones alternating with shales of same color; little change in lithologic character throughout; marine fossils; **Lot 1** was taken near middle............2410

Genesee Series (150′)

32. Shale, dark, hard, fissile, sandy, concealed along State road but can be seen along Browns Creek road about 1 mile north of forks............... 150

Hamilton and Marcellus Series (600′)

33. Concealed. The Hamilton if present, and most of the Marcellus, is concealed under the flood-plain of Knapp Creek. Black, argillaceous, squeezed shale (lower part of Marcellus) exposed at Huntersville......................... 600

Oriskany Series (100′)

34. **Chert, Huntersville,** partly concealed but interval composed of 2″ to 4″ angular blocks of light weathered chert............................ 60
35. **Sandstone, Ridgeley,** poorly exposed but decomposed brown sandstone......................... 40

Salina Series (800′)

stems, bryozoa, etc....................1700

Portage Series (2410′)

31. Sandstone and shale; grayish-green to grayish-brown, fine-grained, platy sandstones alternating with shales of same color; little change in lithologic character throughout; marine fossils; **Lot 1** was taken near middle............2410

Genesee Series (150′)

32. Shale, dark, hard, fissile, sandy, concealed along State road but can be seen along Browns Creek road about 1 mile north of forks.............. 15

Hamilton and Marcellus Series (600′)

33. Concealed. The Hamilton if present, and most of the Marcellus, is concealed under the flood-plain of Knapp Creek. Black, argillaceous, squeezed shale (lower part of Marcellus) exposed at Huntersville...................... 60

Oriskany Series (100′)

34. **Chert, Huntersville,** partly concealed but interval composed of 2″ to 4″ angular blocks of light weathered chert........................ 6

35. **Sandstone, Ridgeley,** poorly exposed but decomposed brown sandstone.................... 4

Salina Series (800′)

36. Concealed

late Dr. I. C. White, while on a visit in that county during the summer of 1927, that this conglomerate probably represented the Gordon Sand of the oil well drillers:

Knapp Creek Section.

Huntersville District; beginning with the Berea Sandstone at the corporate limits on the Marlinton-Huntersville road along Knapp Creek and traversing southeastward along this road to the Minnehaha Springs bridge; measured in descending order.

			Thickness. Feet.	Total. Feet.
Pocono Series (70′)				
1. **Sandstone, Berea,** white, massive, coarse-grained, with abundant quartz pebbles from size of sand grains to 2¼″ in diameter			15	15
2. Shale, light, yellowish-brown, with plants			20	35
3. Sandstone, gray, green and brown, fine-grained, flaggy			25	60
4. Shale, yellow, earthy			10	70
Catskill Series (655′)				
5. **Shale, Saxton,** green at top to gray-blue, micaceous; plant fragments			20	90
6. Concealed and red shale			75	165
7. Sandstone, greenish-brown			10	175
8. Shale, green and red			10	185
9. Sandstone, red and shaly			10	195
10. Shale, red			60	255
11. Sandstone, red, gray, irregular	10′			
12. Shale, variegated	5			
13. Sandstone, gray to blue, concentric weathering, stained with iron	30	**Gordon Sand?**	75	330
14. **Conglomerate,** coarse-grained, with 18″ carbonaceous shale with plant stems near top, abundant quartz pebbles	30			
15. Shale, partly concealed but mostly red			200	530
16. Sandstone, gray, green, red, irregularly bedded			25	555
17. Shale, red, sandy			50	605
18. Sandstone, red, micaceous, cross-bedded			20	625
19. Shale, variegated and sandy			100	725
Chemung Series (3185′)				
20. **Sandstone, Hendricks,** grayish-brown to white sand grains, with flattened quartz pebbles			18	743
21. Shale, brown, sandy			22	765
22. Sandstone, brown, fine-grained			5	770
23. Shale, brown, sandy			25	795
24. Concealed			825	1620
25. Sandstone, greenish-brown, platy and shaly, fossiliferous, **(Lot 52)**			20	1640
26. Concealed, with brown shale			30	1670

		3091
24. Sand, Thirty-foot?, white	31	3122
25. Sand, Gordon Stray?, broken	146	3268
26. Shale	50	3318
27. Sand, Gordon, Fourth and Fifth?, good	245	3563
28. Slate	19	3582
29. Red rock	64	3646
Chemung Series (696′+)		
30. Sand, Hendricks?	36	3682
31. Slate	12	3694
32. Sand	60	3754
33. Slate	13	3767
34. Sand	85	3852
35. Slate and shell to bottom	490	4342

"Hole was drilled 10″ diameter for 120′; 8″ for 1520′; 6¼″ for balance; 660′ of 8″ casing being used. Hole was entirely free from water below casing. No salt water in well at all; a slight showing of oil was found in the upper sand, sufficient to grease the tools and bailer. All sand struck was **very, very hard**".

MEASURED SECTIONS, HUNTERSVILLE DISTRICT.

Huntersville District is situated in the southeastern part of the county and east of the Greenbrier River, comprising the entire drainage basin of Knapp Creek and the headwaters of Anthony Creek, Thomas Creek, and Shock Run, as well as Beaver Creek, Improvement Lick, Monday Lick, Sunday Lick, and Stillhouse Runs. Its surface rocks range from the Pocono down to and including the Red Medina Series.

The following long section, measured by the writer, is unique in many respects since it affords the longest continuous exposure in the county, so that by traversing the State road east from Marlinton along the Knapp Creek gorge to Minnehaha Springs a geologic section from the Berea Sandstone of the Pocono Series down to and including the Red Medina Series can be seen. The section has a total vertical thickness of 9,100 feet of rocks.

The section begins with the conglomeratic Berea Sandstone at the corporate limits and follows the State road along Knapp Creek. At 0.7 mile east of the starting point another conglomerate, coming approximately 200 feet below the

Berea, is well exposed. It was suggested by the late Dr. I. C. White, while on a visit in that county during the summer of 1927, that this conglomerate probably represented the Gordon Sand of the oil well drillers:

Knapp Creek Section.

Huntersville District; beginning with the Berea Sandstone at the corporate limits on the Marlinton-Huntersville road along Knapp Creek and traversing southeastward along this road to the Minnehaha Springs bridge; measured in descending order.

		Thickness. Feet.	Total. Feet.
Pocono Series (70′)			
1. **Sandstone, Berea,** white, massive, coarse-grained, with abundant quartz pebbles from size of sand grains to 2¼″ in diameter		15	15
2. Shale, light, yellowish-brown, with plants		20	35
3. Sandstone, gray, green and brown, fine-grained, flaggy		25	60
4. Shale, yellow, earthy		10	70
Catskill Series (655′)			
5. **Shale, Saxton,** green at top to gray-blue, micaceous; plant fragments		20	90
6. Concealed and red shale		75	165
7. Sandstone, greenish-brown		10	175
8. Shale, green and red		10	185
9. Sandstone, red and shaly		10	195
10. Shale, red		60	255
11. Sandstone, red, gray, irregular	10′		
12. Shale, variegated	5		
13. Sandstone, gray to blue, concentric weathering, stained with iron	30		
14. **Conglomerate,** coarse-grained, with 18″ carbonaceous shale with plant stems near top, abundant quartz pebbles	30		
Gordon Sand?		75	330
15. Shale, partly concealed but mostly red		200	530
16. Sandstone, gray, green, red, irregularly bedded		25	555
17. Shale, red, sandy		50	605
18. Sandstone, red, micaceous, cross-bedded		20	625
19. Shale, variegated and sandy		100	725
Chemung Series (3185′)			
20. **Sandstone, Hendricks,** grayish-brown to white sand grains, with flattened quartz pebbles		18	743
21. Shale, brown, sandy		22	765
22. Sandstone, brown, fine-grained		5	770
23. Shale, brown, sandy		25	795
24. Concealed		825	1620
25. Sandstone, greenish-brown, platy and shaly, fossiliferous, (Lot 52)		20	1640
26.			1670

	Thickness. Feet.	Total. Feet.
27. **Sandstone, Elkins,** reddish-brown, fine-grained, **Atrypa hystrix zone**	15	1685
28. **Sandstone, Elkins** (continued), greenish to reddish-brown thick flagstone, fine-grained and alternating with brown sandy shale; heavier bedded at base; marine fossils along with tree trunks in horizontal position flattened on bottom and semicircular on underneath side	50	1735
28a. **Sandstone, Elkins,** (continued), somewhat shaly; numerous marine fossils	150	1885
28b. **Sandstone, Elkins,** (continued), blue-green on fresh fracture, but weathering brown; fine-grained; massive; contains large stump and portions of tree trunks	50	1935
29. Sandstone, brown, fine-grained, alternating with brown, sandy shale	275	2210
30. Sandstone, predominating, gray and brown, alternating with shale; heavier bedded sandstone near base. Lower portion contains sufficient marine shells to form layers of limestone. **(Lot 35) Atrypa hystrix, Spirifer disjunctus, crinoid** stems, bryozoa, etc	1700	3910
Portage Series (2410′)		
31. Sandstone and shale; grayish-green to grayish-brown, fine-grained, platy sandstones alternating with shales of same color; little change in lithologic character throughout; marine fossils; **Lot 1** was taken near middle	2410	6320
Genesee Series (150′)		
32. Shale, dark, hard, fissile, sandy, concealed along State road but can be seen along Browns Creek road about 1 mile north of forks	150	6470
Hamilton and Marcellus Series (600′)		
33. Concealed. The Hamilton if present, and most of the Marcellus, is concealed under the flood-plain of Knapp Creek. Black, argillaceous, squeezed shale (lower part of Marcellus) exposed at Huntersville	600	7070
Oriskany Series (100′)		
34. **Chert, Huntersville,** partly concealed but interval composed of 2″ to 4″ angular blocks of light weathered chert	60	7130
35. **Sandstone, Ridgeley,** poorly exposed but decomposed brown sandstone	40	7170
Salina Series (800′)		
36. Concealed ... 600′ 37. Limestone, impure, with ostracods; **(Lot 2)** ... 4 38. Shale, dark ... 8 39. Limestone, impure, gray, weathers yellow ... 2 40. Shale, calcareous ... 3 41. Concealed ... 158 **Helderberg, Bossardville, and Rondout Groups**	775	7945
42. **Sandstone, Bloomsburg?,** grayish-brown, quartzitic, 4″ to 18″ flaggy layers	25	7970

	Thickness. Feet.	Total. Feet.
Niagara Series (40′)		
43. Shale, dark, but mostly concealed	40	8010
Clinton Series (501′)		
44. Sandstone, thin-bedded, shaly ... 4′ 45. Sandstone, brown, quartzitic ... 8 46. Sandstone, brown, thin-bedded, shaly ... 6 **Keefer**	18	8028
47. Shale, yellow and gray, thin-bedded, fossiliferous (**Lot 3**)	52	8080
48. Shale, variegated, with platy sandstones	30	8110
49. Shale, variegated, sandy, alternating with 1″ to 6″ limestone	12	8122
50. Iron ore, red, **Fossil Ore Horizon** (0′ 7″)	1	8123
51. Limestone, impure, siliceous	5	8128
52. Sandstone, dark, calcareous (23′ 5″)	23	8151
53. Shale, yellow and green, sandy, alternating with platy sandstones 1″ to 3″ thick, with occasional thin limestones	20	8171
54. Shale, mashed, yellowish-brown, fissile, estimated	200	8371
55. Sandstone and shale, red, **Iron Sandstone;** 1″ to 2″ layers alternating with variegated shales	50	8421
56. Shale, brown, sandy	20	8441
57. Sandstone, red, ferruginous, platy	10	8451
58. Shale and sandstone, variegated	60	8511
White Medina Series (188′)		
59. Sandstone, gray, massive, quartzitic	6	8517
60. Sandstone, gray or brown, platy, 1″ to 6″ layers, alternating with dark sandy shales	24	8541
61. Sandstone, white, massive, quartzitic, with fucoids	12	8553
62. Sandstone, shaly	10	8563
63. Sandstone, massive, quartzitic	30	8593
64. Shale, dark and variegated	6	8599
65. Sandstone, massive, quartzitic .... 86′ 10″ White quartzite, fine pebbles 1′ 2″ Quartzite, abundant quartz pebbles ... 4 0 Massive quartzite, pebbles sparse, except at base, with 3″ iron sandstone conglomerate ... 8 0 13 2	100	8699
Red Medina Series (401′)		
(The upper 18′ 0″ although recorded under the Red Medina Series are truly transitional).		
66. Sandstone, light, argillaceous ... 2′ 6″		
67. Sandstone, greenish-brown, alternating with sandy shale ... 5 0		
68. Sand		

The following section, measured by the writer in company with Andrew Price of Marlinton, shows a peculiar development of beautifully colored laminated clays in the Helderberg Limestone Series. Two samples of these clays were collected for analysis the results of which appear as Samples Nos. 22 and 23:

Rainbow Run* Section.

Huntersville District; along Rainbow Run, one mile northeast of Browns Creek School; traverse eastward.

		Thickness. Feet.	Total. Feet.
Marcellus Series (120′ exposed)			
1. Shale, black, with large septarian nodules, **Lower Selinsgrove Limestone**		30	30
2. Concealed, **Selinsgrove Shale horizon**		90	120
Oriskany Series (130′)			
3. Chert, **Huntersville**, dark-gray, hard		55	175
4. Sandstone, brown, massive ... 10′	**Ridgeley**	75	250
5. Conglomerate, "wheat grain", small quartz pebbles about the size of rice or wheat grains ... 5			
6. Sandstone, earthy-brown, coarse-grained, with fossil pits ... 60			
Helderberg Series (380′)			
7. Concealed		150	400
8. Clays, siliceous, finely laminated, all colors; see description of Helderberg Series		230	630
Salina Series—Bossardville Group (325′)			
9. Concealed		325	955
Salina Series—Rondout Group (100′)			
10. Limestone, light gray, platy and shaly		100	1055
Niagara Series (90′)			
11. Limestone, gray, thin, interbedded with shale		90	1145
Clinton Series (465′)			
12. Sandstone, grayish-brown quartzitic ... 5′	**Keefer**	25	1170
13. Shale, dark, sandy ... 1			
14. Sandstone, shaly ... 9			
15. Sandstone, earthy ... 10			
16. Shale, yellow and brown, alternating with 8″ to 12″ of very fossiliferous limestone strata in upper portion (**Lot 12**)		300	1470
17. Sandstone, **Iron**, red, quartzitic and oolitic. Partly concealed in dip of ravine		40	1510
18. Concealed to White Medina		100	1610
White Medina Series (50′)			
19. Sandstone, white, quartzitic; makes arch..		50	1660

The following section, measured by the writer, affords an opportunity to study the relation between the Catskill Series and overlying Pocono Series. Here the Berea Sandstone rests directly upon the red shales. On a second visit to this locality in company with Dr. David White and David B. Reger, a slab of sandstone which was undoubtedly from the Saxton horizon, and which was matted with bony fish plates and conical fish teeth, was picked up. See Dr. John L. Tilton's discussion of this collection (Lot No. 45) under Paleontology:

Fair-Grounds Section.

Huntersville District; along the Chesapeake and Ohio Railway track one mile northeast of Marlinton and opposite the Fair-Grounds; traverse southeastward.

			Thickness. Feet.	Total. Feet.
Pocono Series (100′+)				
1. Shale, Sunbury, yellowish-brown to dark, alternating with thin brown to dark sandstone.....			35	35
2. Sandstone, fine-grained, green, platy; thin sandstone conglomerate near middle.....	25′	**Berea**	65	100
3. Sandstone, conglomeratic, earthy-brown; large and small quartz pebbles	15			
4. Shale, olive-brown, alternating with grayish-brown micaceous sandstones 3″ to 6″ thick	10			
5. Sandstone, grayish-brown, cross-bedded..	15			
Catskill Series (220′+)				
6. Sandstone, red and gray with lenses of red shale			20	120
7. Shale, red and olive; sandy and dark at top	15′	**Saxton Shale**	55	175
8. Shale, red, sandy, with 8″ of green shale near top	25			
9. Sandstone, grayish-brown	5			
10. Shale, gre				

	Thickness. Feet.	Total. Feet.
12. Sandstone, gray and brown	5	205
13. Sandstone, red, shaly	15	220
14. Shale, red, and concealed	100+	320+

MEASURED SECTIONS, LITTLE LEVELS DISTRICT.

Little Levels District is situated in the southwestern part of Pocahontas and comprises the remainder of the county southwest of Edray and Huntersville Districts. It extends southward from the divide between the waters of Williams River and Middle Fork, including the watershed of the latter stream, Cranberry River, Cherry River, and Hills Creek, and crosses east of the Greenbrier River to include the area south of Beaver Creek and west of North Fork of Anthony Creek. Within its limits an almost complete geologic column of the county is represented, including the lower portion of the Kanawha Group of the Pottsville Series on Yew Mountain, down to and including the White Medina Series on Beaver Lick Mountain.

The following section, measured by the writer, is composed entirely of the three basal groups of the Mauch Chunk Series which are found along the trail from Stamping Creek to the low divide between this stream and Cranberry River, and thence to the high point on Cranberry Mountain. The section has been arranged in descending stratigraphic order:

Stamping Creek Section.

Little Levels District; beginning at a high point (4215′ B.) on Cranberry Mountain and traversing southwestward to the trail crossing low divide at head of Stamping Creek and thence southeastward along the trail to Raintown; measurement by aneroid.

	Thickness. Feet.	Total. Feet.
Mauch Chunk Series—Princeton Group (10′)		
1. **Sandstone, Princeton**; point capped by boulders of conglomerate	10	10
Mauch Chunk Series—Hinton Group (480′)		
2. Concealed		

	Feet.	Feet.
7. **Sandstone, Stony Gap,** brown, hard, fine-grained; weathers white; makes low gap at divide, exposed	15	490
Mauch Chunk Series—Bluefield Group (1045′)		
8. Concealed	200	690
9. **Sandstone, (Big Spruce Knob),** light-brown, massive; makes bluff	75	765
10. Shale, red	25	790
11. Concealed	25	815
12. Sandstone, reddish-brown, massive, fine-grained; weathers white	50	865
13. Concealed	260	1125
14. Sandstone, red, cross-bedded; makes bluff	10	1135
15. Shale, red	20	1155
16. Shale, dark (has been prospected for coal)	5	1160
17. Shale, red	20	1180
18. Concealed	45	1225
19. Shale, red	50	1275
20. Concealed	120	1395
21. Limestone, shaly, fossiliferous .... 15′		
22. Shale, gray or brown, calcareous .... 10 — **Reynolds Limestone**	40	1435
23. Limestone, shaly, fossiliferous 15		
24. Shale, dark and olive	45	1480
25. **Limestone, Glenray,** dark, fossiliferous	5	1485
26. Concealed	10	1495
27. **Sandstone, Edray,** grayish-brown, fine-grained	10	1505
28. **Shale, Lillydale,** dark-green, red and sandy	30	1535
Greenbrier Series (45′+)		
29. **Limestone, Alderson,** cross-bedded, impure, shaly, with 5′ of gray oolite	20	1555
30. Limestone, reddish-gray, massive, cross-bedded; crinoid stems and plates, brachiopods, cup corals, and **Archimedes**; 1′ of limestone and mud-ball concretion near top	25	1580

The following section, measured by the writer and arranged in descending stratigraphic order, affords a view of the basal Coal Measures including the **Sewell Coal.** A complete section of the Mauch Chunk Series was measured by aneroid, using vertical measurements on rising strata, thus shortening its true thickness by approximately 400 feet. An attempt was made to reopen the Sewell Coal here at the prospect of the Preston Clark Heirs, from which considerable

Briery Knob Section.

Little Levels District; beginning at high point on Briery Knob and following southeastward along the old coal road to forks near Mt. Lebanon Church and thence northeastward to Hills Creek.

				Thickness. Feet.	Total. Feet.
Pottsville Series—New River Group (431′)					
1.	**Sandstone, (Harvey Conglomerate)**, grayish-brown, weathering almost white, coarse......			15	15
2.	Concealed in flat bench........................			90	105
3.	**Sandstone, Guyandot**, white, weathering to white sand, coarse; small white quartz pebbles.....			55	160
4.	**Shale, Hartridge**, mostly concealed, but 4′ of dark carbonaceous shale with plants and **Naiadites?** visible			35	195
5.	**Coal**, good, clean...	2′ 4″	(6′ 5″)		
6.	Shale	1 10	**Sewell**, Preston		
7.	**Coal**, good, clean...	1 3	Clark Heirs Prospect		
8.	**Coal**, concealed.....	1 0	**(No. 11 on Map II)**...	6.4	201.4
9.	Concealed				
10.	Concealed, flat bench.........................			24.6	226
11.	**Sandstone, Upper Raleigh (Sharon)**, brown and white, coarse, cross-bedded, with white quartz pebbles			105	331
12.	Concealed			95	426
13.	Shale, dark, carbonaceous, **Fire Creek Coal horizon**			5	431
Mauch Chunk Series—Bluestone Group (297′)					
14.	Sandstone, reddish-brown, shaly................			5	436
15.	Concealed			52	488
16.	Concealed in flat bench........................			165	653
17.	Shale, yellow..................................			5	658
18.	Concealed			70	728
Mauch Chunk Series—Princeton Group (50′)					
19.	Concealed in bench but large conglomerate boulders (**Princeton Sandstone**)..................			50	778
Mauch Chunk Series—Hinton and Bluefield Groups (1018′)					
20.	Shale, red.....................................			200	978
21.	**Sandstone, Stony Gap**, red and brown, cross-bedded, makes bold cliff, shaly at top........			40	1018
22.	Shale, red.....................................			125	1143
23.	Sandstone, grayish-brown, micaceous...........			25	1168
24.	Shale, red.....................................			20	1188
25.	Shale, partly concealed, but mostly red.........			250	1438
26.	Sandstone, red.................................			5	1443
27.	Shale, red.....................................			105	1548
28.	Sandstone, reddish-brown			10	1558
29.	Shale, red.....................................			25	1583
30.	Sandstone, red.................................			3	1586
31.	Shale, red, green, sandy.......................			30	1616
32.	Shale, yellow, olive, to road forks (2715′ B.)....			40	1656
33.	Shale, olive, dark.............................			10	1666
34.	**Limestone, Reynolds**, very fossiliferous, impure, shale at top..............................			20	1686

	Thickness. Feet.	Total. Feet.
Greenbrier Series (210′+)		
39. **Limestone, Alderson,** massive, gray, fossiliferous	10	1806
40. Concealed	90	1896
41. **Shale, Greenville,** dark, carbonaceous, fossiliferous	40	1936
42. Concealed to Hills Creek (2465′ B.)............	70	2006

The following section was measured by the writer from the top of Droop Mountain, where the Droop Sandstone can be seen to its best advantage. The broad flat top of this mountain is now covered with thick deposits of sand as the weathered product of this sandstone. This sand is fine-grained but remarkably free from impurities. See chemical analyses of Samples Nos. 53 and 64. The same ground has been previously covered by Reger, in an unpublished section which the writer has been permitted to inspect:

Droop Mountain Section.

Little Levels District; starting on Droop Mountain about ½ mile southwest of Spice Post-Office and traversing northeastward along the new State road, in general along the strike, to base of Taggard Limestone; thence offsetting southeastward ¼ mile, and continuing to Greenbrier River at Mill Run; measured with aneroid and hand-level.

			Thickness. Feet.	Total. Feet.
Mauch Chunk Series—Bluefield Group (309′)				
1. **Sandstone, Droop** (type locality), light-brown to white, massive, weathering to white sand, cap rock of Droop Mountain.......................			40	40
2. Shale, partly concealed, but greenish.........	50′	**Ada**	60	100
3. Shale, dark, fissile, carries septarian nodules, which upon breaking reveal fissures filled with calcite..........	10			
4. Limestone, dark, massive, fossiliferous....	5′	**Reynolds Limestone**	50	150
5. Shale, brown, calcareous, with limestones 1″ to 2″ thick.............	20			
6. Limestone, dark, hard	3			
7. Shales and limestone; dark shales and thin limestone	5			
8. Limestone, light-blue, shaly, impure, fossil				

		Thickness, Feet.	Total, Feet.
9. Shale, dark, calcareous 13'	Bickett Shale	18	168
10. Shale, red 5			
11. Sandstone, Webster Springs, reddish-brown, shaly		10	178
12. Shale, red		6	184
13. Limestone, Glenray, gray, fossiliferous, shaly at top and bottom		20	204
14. Shale, dark-green, with occasional sand and red shale 55'	Lillydale Shale	105	309
15. Shale, red and brown, sandy 50			
Greenbrier Series (605')			
16. Limestone, upper part crystalline, cross-bedded, fossiliferous 15'	Alderson Limestone	40	349
17. Limestone, dark, weathering yellow, pitted, brachiopods (Composita), crinoids (Pterotocrinus) 20			
18. Limestone, red, uneven-textured, breccia-like; contains bryozoa, (Archimedes), Composita 5			
19. Limestone, oolitic, beautiful, massive, fossiliferous		15	364
20. Shale, Greenville, red and brown, with shaly limestone		30	394
21. Limestone, Union, dark-gray, fossiliferous, shaly at top; lower part oolitic with pink-colored fossils, giving beautiful polished surface, brachiopods (Productus, etc.), crinoids		30	424
22. Limestone, Pickaway (may be part Union), dark-gray, siliceous 100'	Pickaway Limestone	205	629
23. Shale, red 5			
24. Limestone, Pickaway (continued), partly concealed, shaly 100			
25. Limestone, Taggard, gray, oolitic, fossiliferous, with streaks of red shale		25	654
26. Limestone, Patton, dark, siliceous		100	754
27. Limestone, Patton, (continued), gray, pure, fossil corals and crinoids		20	774
28. Limestone, Patton, (continued), dark, siliceous, impure		20	794
29. Limestone, Patton, (continued), dark-gray and oolitic		50	844
30. Shale, Patton, red		5	849
31. Limestone, Sinks Grove, dark and hard, with marine fossils, lower portion shaly and streaked with green		50	899
32. Limestone, Hillsdale, (St. Louis age as correlated			

	Thickness. Feet.	Total. Feet.
Pocono Series (210')		
35. **Sandstone, Broad Ford**, reddish-brown, thick-bedded, fine-grained, with marine fossils	190	1170
36. Shale, green	5	1175
37. Concealed to Greenbrier River	15	1190

The following section was measured by the writer primarily to show the relation of the Catskill Series to the overlying Pocono Series. A clean exposure here shows a slight angular unconformity between the two:

Stevens Hole Run Section.

Little Levels District; along Greenbrier River at mouth of Stevens Hole Run.

			Thickness. Feet.	Total. Feet.
Pocono Series (95'+)				
1. Concealed				
2. Shale, brown, sandy			10	10
3. Sandstone, bluish-gray, fine-grained	20'	**Berea Sandstone**	85	95
4. Sandstone conglomeratic, with white quartz pebbles	5			
5. Sandstone, grayish-brown, irregularly bedded	15			
6. Shale, brown, sandy, ferruginous, with quartz pebbles	4			
7. Sandstone, gray and brown, massive	10			
8. Conglomerate, earthy and ferruginous, with large and small quartz pebbles	1			
9. Sandstone, greenish-gray, micaceous, speckled with iron; weathers brown	30			
Unconformity (slightly angular)				
Catskill Series (17'+)				
10. Shale, brown, sandy			4	99
11. Shale, red, sandy				

the county and comprises the entire area north of a line from Mace to Raywood and thence along the east side of Greenbrier River to Clover Lick and thence in a meandering line to the Virginia State line on Allegheny Mountain. Its surface rocks range from the Kanawha Group of the Pottsville Series down nearly to the top of the Red Medina. Opportunities for measuring good sections are not readily afforded, since the area north of the Staunton and Parkersburg Pike has practically no roads with very few trails. The precipitous Back Allegheny Mountains is likewise very inaccessible either on foot or horseback. The best opportunity for a section of any length is along the new road cuts on the Staunton and Parkersburg Pike from the divide on Back Allegheny to the Greenbrier River at Durbin. A section measured along this road reveals the decrease in thickness of the Mauch Chunk, Greenbrier, and Pocono Series with an increase in the Catskill Series as contrasted to the same series in the southern end of the county. The section, which covers the same ground as an unpublished measurement by Reger but which differs in certain details of correlation and interpretation, is as follows:

Durbin Section.

Greenbank District; beginning on Back Allegheny Mountain ¾ mile south of where the Staunton and Parkersburg Pike crosses the Pocahontas-Randolph County line and traversing northward to this point and then southeast along this pike to the West Fork of the Greenbrier River at Durbin; dip is to the northwest 10° to 18°; arranged in descending order; measurement with aneroid and hand-level.

	Thickness. Feet.	Total. Feet.
Pottsville Series—New River Group (165'+)		
1. **Sandstone, Sharon (Upper Raleigh)**, conglomeratic: white sand grains with white quartz pebbles, 15' to	25	25
2. Concealed	140	165

		Feet.	Feet.
	Mauch Chunk Series—Bluefield Group (435′)		
5.	Shale, red	25	750
6.	Shale, red and grayish-green, sandy	20	770
7.	**Sandstone, (Big Spruce Knob),** grayish-brown, massive, fine-grained	30	800
8.	Shale, red	140	940
9.	Concealed	40	980
10.	Shale, red	30	1010
11.	Concealed and red shale	35	1045
12.	**Sandstone, Droop?,** red, cross-bedded	15	1060
13.	Shale, red and green	10	1070
14.	Limestone, hackly, impure, weathering yellow, very fossiliferous; **Orthotetes, Spirifer,** crinoid stems, cup corals, bryozoa, gastropods .... 15′		
15.	Shale, red 10		
16.	Limestone, red, siliceous, with fossils... 10		
17.	Limestone, blue, weathering yellow.......... 10		
	Reynolds, (Top, 3400′ B.)	45	1115
18.	**Sandstone, Webster Springs,** reddish-brown	5	1120
19.	Shale, red	10	1130
20.	**Limestone, Glenray,** red and shaly	10	1140
21.	Concealed	20	1160
	Greenbrier Series (205′)		
22.	**Limestone, Alderson,** hackly at top, weathering yellow; contains **Orthotetes, Composita,** crinoids, and gastropods. (See **Lot 24**). Base is dark-gray, massive, and cross-bedded	40	1200
23.	**Sandstone, Cypress,** red, shaly	20	1220
24.	**Limestone, Union, (Gasper portion),** red, cross-bedded, siliceous, streaked with calcite at top but grading into gray; weathers white; pure oolite	50	1270
25.	**Sandstone, Bethel,** red, shaly, calcareous	10	1280
26.	**Limestone, Union, (Fredonia portion),** gray, weathering white, oolitic	35	1315
27.	Concealed	40	1355
28.	**Limestone, Patton,** greenish-gray, earthy	10	1365
	Maccrady Series (30-40′)		
29.	Shale, red, partly concealed	40	1405
	Pocono Series (60′)		
30.	Concealed and grayish-brown sandstone	20	1425
31.	**Sandstone, Berea,** grayish-brown, with small quartz pebbles	40	1465
	Catskill Series (840′)		
32.	Shale, red and olive	15	1480
33.	Sandstone, olive-brown, shaly	15	1495
34.	Shale, red, green and olive	15	1510
35.	Sandstone, gray or brown, shaly at base	30	1540

	Feet.	Feet.
40. Shale, yellow, sandy	20	1635
41. Sandstone, gray, brown or red, cross-bedded	40	1675
42. Shale, red, green or olive, sandy	200	1875
43. Sandstone (plant collection by Reger, David White, and Price*), grayish-green to brown shaly near middle	150	2025
44. Shale, red, very sandy	10	2035
45. Sandstone, greenish-gray, platy, weathering brown; makes cliff	30	2065
46. Shale, olive, red or green	15	2080
47. Sandstone, blue or green, with carbonized plants, (collection by Reger, White, and Price*)	25	2105
48. Concealed at bend (2890' B.)	100	2205
49. Sandstone, grayish-green	10	2215
50. Shale, olive-green	10	2225
51. Shale, olive-green	5	2230
52. Sandstone, green, with lenses of red; makes cliff at bridge over West Fork of Greenbrier River at Durbin	25	2255
53. Concealed, with sandstone in bed of river	25	2280
54. Sandstone, reddish-brown, with red and green shale in Western Maryland Railway cut	15	2295
55. Sandstone, green, medium-coarse, in railway cut	10	2305
Chemung Series ( )		
56. **Sandstone, Hendricks,** green, flaggy, with fossils; crinoids and brachiopods; exposed just east of railway		

MEASURED SECTIONS IN ADJOINING COUNTIES.

It is considered advisable in a geological report of this kind to include such available information on adjoining areas as may be necessary to show the relation thereto. This is often the case, where opportunities are afforded beyond the limits of a county under discussion where better conditions for study are present. This condition is true with reference to the adjoining area on the west as well as a portion of the area to the north. The following sections are therefore included in this report.

The following section is a record of the W. Va. Pulp and Paper Company coal test boring on Snyder Knob, Mingo District, Randolph County, located two miles northwest of the Pocahontas County line and 0.7 mile west of Hopkins. The interpretations are by Reger. The section is an important one for this area since it affords an opportunity to study in detail the remaining Pottsville Series with

Table Showing Thickness at Measured Sections of Pocahontas and Adjacent Areas.

	Kanawha	New River	Bluestone	Princeton	Hinton	Bluefield	Greenbrier	Maccrady	Pocono	Catskill	Chemung	T
....	....	150+	110	70	545	731	407	30	253+	....	....	2
....	....	....	....	....	....	....	....	....	450	....	....	
Springs........	....	....	....	....	....	....	25+	23	50+	....	....	
....	....	....	....	....	....	....	....	....	....	400	....	
....	(640)		100	50	(1020)		....	....	....	....	....	1
....	....	500	100	50	415	815	10+	....	....	....	....	1
....	....	....	....	....	....	280+	500	20	41+	....	....	
a........	....	100+	100	50	535	740	510	30	210	70+	....	2
Knob........	....	40+	240	40	(1597)		546	....	309	874	696+	4
s	....	....	....	....	....	....	....	....	100+	220+	....	
reek........	....	....	....	10+	480	1045	45+	....	....	....	....	1
....	....	431+	297	50	(1018)		210+	....	....	....	....	2
tain........	....	....	....	....	....	309+	605	66	210+	....	....	1
e Run........	....	....	....	....	....	....	....	....	95+	17+	....	
....	....	165+	(560)			435	205	30–40	60	840	( )	2
s Gauley........	200+	530	180	....	....	....	....	....	....	....	....	
Williams........	115+	595	175	....	....	....	....	....	....	....	....	
....	300	580	....	....	....	....	....	....	....	....	....	
b........	(381)		113+	....	....	....	....	....	....	....	....	

Showing Thickness at Measured Sections of Pocahontas and Adjacent Areas (Continued

	Pocono	Catskill	Chemung	Portage	Genesee	Hamilton	Marcellus	Oriskany	Helderberg	Bossardville	Rondout	Niagara	Clinton	White Medina	Red Medina	T
k......	70+	655	3185	2410	150	(600)		100	(	800	)	40	501	188	401	9
an......	......	......	......	......	......	......	120+	130	380	325	100	90	465	50	......	1

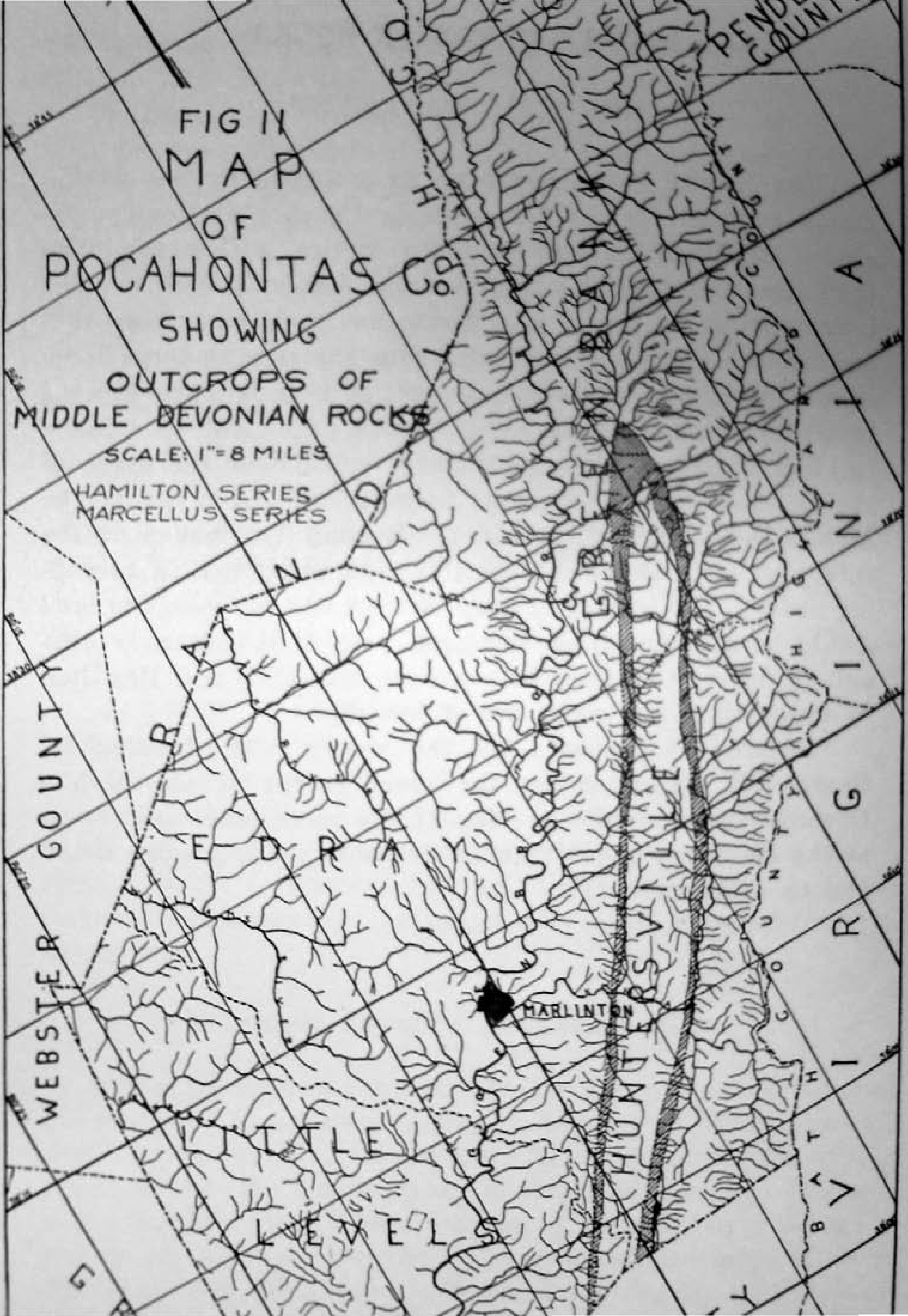
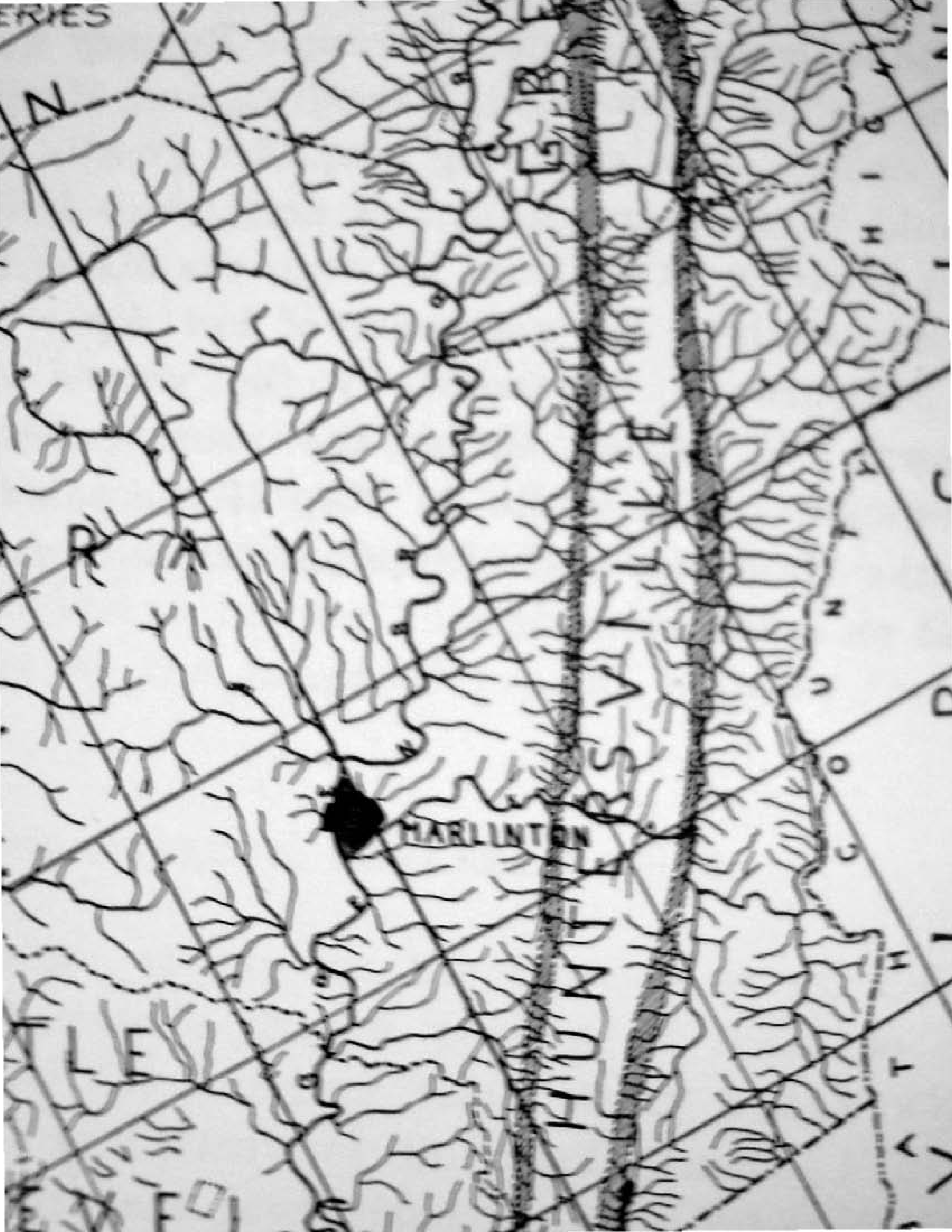


FIG 11
MAP
OF
POCAHONTAS CO.
SHOWING
OUTCROPS OF
MIDDLE DEVONIAN ROCKS
SCALE: 1" = 8 MILES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MARLINTON
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GENERAL ACCOUNT, HAMILTON SERIES.

The Hamilton Series, comprising the upper division of the Middle Devonian beds, and coming just below the Genesee Series, is composed very largely of greenish-gray shales in the fresh exposures but generally weathers to a chocolate-brown or brownish-buff. The lower or more carbonaceous shales weather gray like the Marcellus below. In fact the actual occurrence of this series in Pocahontas County was so uncertain that several collections were made from its supposed horizon in order to prove or disprove its presence, with the result that approximately one hundred feet of these shales as above described contained fossils that are evidently of Hamilton age. On the basis of these identifications this succession of beds coming between those definitely recognized as Marcellus and Genesee is mapped and discussed as the Hamilton Series.

SUBDIVISIONS, HAMILTON SERIES.

From the few exposures that are recognized as Hamilton, which is apparently a single lithologic and faunal unit, subdivision by either of these characteristics was not possible.

TOPOGRAPHIC EXPRESSION, HAMILTON SERIES.

The Hamilton Series in Pocahontas contains neither resistant sandstone nor massive ledges, being composed of weak shales. It does not form prominent ridges or escarpments, and when present in nearly horizontal position makes only low and rolling hills. In this area, however, these beds are generally found standing with steep dips, but eroded to the valley bottoms along with the Marcellus.

AREAL EXTENT, HAMILTON SERIES.

Hamilton, like the overlying Genesee, is found only east of the Greenbrier River. Its exposures are limited to two, which enter the county on the south on either side of the Browns Mountain Anticline and parallel this structural feature to the vicinity of Arbovale where they unite in this plunging anticline to disappear beneath the Genesee Series. As noted in sections that include this horizon the interval is generally concealed. The exposure at which **Lot 13** was collected is 0.2 mile northeast of Westminster Church at elevation 2,375.

CONTACTS, HAMILTON SERIES.

The upper contact of the Hamilton Series with the overlying Genesee has already been discussed under the description of the latter series on page 219. The lower contact with the Marcellus is very difficult to draw since the beds of the lower portion of the Hamilton are very similar to those in the upper portion of the Marcellus. The line is drawn where the arenaceous shales come in above the more argillaceous and carbonaceous shales of the Marcellus. There is a marked contrast between the soils of these two series. The Hamilton weathers to a reddish-brown sandy loam while the Marcellus weathers to a gray and yields a clay soil. The absence of typical Hamilton fossils increases the uncertainty of this contact.

FOSSIL LIFE, HAMILTON SERIES.

The usual profuse marine life that is found in the Hamilton Series throughout the Appalachian States to the northeast is noticeably absent in Pocahontas County. The general absence of these fossils might cause a belief that this series is almost, if not entirely, absent in this area, but among the numerous collections made from the Lower Devonian shales two are recognized as of Hamilton age. Along the State highway (Route 42) 0.2 mile northeast of Westminster to the Hamilton in both New York and Maryland. **Lot 27,** which was collected by the writer, with identifications by Tilton, from road ballast, at the south end of the Huntersville bridge, because of its Hamilton appearance, contained **Chonetes coronatus**, **Spirifer consobrinus**, and **Ambocoelia virginiana** in abundance. The latter species is found both in the Hamilton and Marcellus, but the other two are found only in the Hamilton.

CORRELATION, HAMILTON SERIES.

In view of the foregoing discussion it seems safe to correlate that succession of beds in Pocahontas County lying between those of typical Genesee character and those of Marcellus character with the Hamilton of New York.

DESCRIPTION OF MEMBERS, HAMILTON SERIES.

Comment has already been made on the difficulty of attempting to separate the Hamilton Series in Pocahontas County into members. From the limited exposures available, few, if any, lithologic differences were noted, and from the meager fauna, subdivision on that ground would also be impossible.

ECONOMIC ASPECTS, HAMILTON SERIES.

The Hamilton Shales are of minor economic importance, containing no minerals in commercial quantities and being too sandy for general ceramic products. Although limited in quantity, the shales are admirably adapted for the construction of light-traffic roads. They seem to contain the right mixture of sand and clay for a natural road base.

MARCELLUS SERIES.

GENERAL ACCOUNT, MARCELLUS SERIES.

Because of this carbon content they have a tendency to weather light colored on exposure. Toward the base of this series there occur thin impure limestones along with calcareous shales. At many localities large concretionary and septarian nodules of ferruginous and calcareous character are common. (See Plate XXXVIII). In Pocahontas County, the Marcellus Series is confined to the area comprising the Browns Mountain Anticline, and has therefore been subjected to considerable pressure by folding. For this reason it is impossible to get the exact thickness in any of the exposures visited, because of the repetition of beds by minor folding, or thinning due to lateral compression, but the Marcellus retains, in this area, an approximate thickness of 500 feet.

SUBDIVISIONS, MARCELLUS SERIES.

In conformity with previous Reports of the West Virginia Geological Survey, the Marcellus Series is subdivided as follows:

	Thickness. Feet.	Total. Feet.
Marcellus Series		
Shale, black, fissile, carbonaceous; typical Marcellus fauna and lithology............	100 to 300	300
Limestone, Lower Selinsgrove, black, carbonaceous, shaly, carrying Marcellus and Onondaga faunas.........................	50 to 100	400
Shale, Lower Selinsgrove, black, fissile, carbonaceous, calcareous; mixed Marcellus and Onondaga faunas......................	50 to 100	500

The Marcellus can be subdivided into an upper shaly portion and a lower calcareous and shaly portion. The lower division is variable and can usually be subdivided into an upper calcareous portion (Lower Selinsgrove Limestone), and a lower shale (Lower Selinsgrove Shale). The lower shale overlies the Oriskany Series and frequently carries ondaga and early Marcellus time.

TOPOGRAPHIC EXPRESSION, MARCELLUS SERIES.

The Marcellus shales are the most easily eroded series of rocks exposed in Pocahontas County. The low valleys on either side of the Beaver Lick-Browns-Michael Mountain area are largely formed in this series, as well as the flat land around Green Bank and Arbovale. These bottoms are frequently covered by alluvial material.

AREAL EXTENT, MARCELLUS SERIES.

On Figure 11 the Marcellus Series is included under the Middle Devonian Rocks, but it can be seen in much greater detail and on a larger scale on Map II. This series is also confined to the east side of Greenbrier River, and to the Browns Mountain Anticline. It enters the county from the south on either side of this complex folded area and parallels this structural feature to the vicinity of Green Bank and Arbovale where its outcrop broadens by minor folding and passes beneath the younger rocks. The Marcellus Series can be seen to good advantage at many points along its outcrop. Along the Green Bank-Marlinton highway on either side of Browns and Michael Mountains many opportunities are afforded to examine it.

CONTACTS, MARCELLUS SERIES.

The upper contact of the Marcellus with the overlying Hamilton has already been discussed under the description of the latter series on page 224, attention being called to the absence of a definite plane. At the base, however, the contact is much more pronounced, with the black and fissile, typical Marcellus shale resting upon a yellowish-gray to dark the base of the Marcellus, which may be contemporaneous with Onondaga, as the 50 to 75 feet of chert (Huntersville, to be discussed later) may be contemporaneous with the Schoharie or Esopus of New York. The discussion of this phase would seem to be more appropriate under the Oriskany Series.

FOSSIL LIFE, MARCELLUS SERIES.

The Marcellus Series is, as a whole, sparingly fossiliferous. Aside from the fossils occurring in the lower calcareous portion, the life forms are limited to a few species. **Styliolina fissurella** is the most common, with **Liorhynchus limitare** and a few other forms occasionally found. Since fossil collections were made primarily for stratigraphic mapping, and as the Marcellus is generally followed with slight difficulty because of its lithologic character, few collections were made from this series. **Lot 20,** collected by the writer immediately east of Cove Hill School, one mile northwest of Frost, with identifications by Dr. John L. Tilton, contained the following species: **Anoplotheca acutiplicata, Ambocoelia virginiana, Buchiola halli, Platyostoma, Styliolina fissurella,** and **Tentaculites.**

CORRELATION, MARCELLUS SERIES.

From this single collection, correlation on faunal evidence would be of little value. The upper bed of black fissile shale varying from 100 to 300 feet in thickness is without apparent lithologic variation. It is this upper portion that is limited to the Marcellus by the Maryland Geological Survey. In the lower half of the series the lithology is somewhat variable, but is generally recognized as being further subdivided into an upper and calcareous portion and a lower black shale. Kindle[18] correlates this lower calcareous portion with the Onondaga of New York, primarily on the basis of its faunal relationship. The writer is in accord with this contention, especially throughout the Appalachian States to the northeast. The by restricted-sea conditions during late Onondaga and early Marcellus time. A limestone occurring at what appears to be the same stratigraphic horizon near Selinsgrove in central Pennsylvania was named the **Lower Selinsgrove** by Dr. I. C. White, but contains, according to Kindle[11] Onondaga fauna. Dr. White, however, in Report G7 of the Second Geological Survey of Pennsylvania, pages 80-81, distinctly states that the Lower Selinsgrove Limestone lies entirely above the true Corniferous (Onondaga) Limestone. This same horizon has been recognized throughout the Allegheny Mountain counties in West Virginia and correlated as such. For the sake of uniformity this same nomenclature is retained in this report.

DESCRIPTION OF MEMBERS, MARCELLUS SERIES.

Marcellus Shale.

The black, fissile, and carbonaceous shale occurring at the top of the series is generally recognized by most authors as representative of the New York Marcellus. This upper member is present in Pocahontas County and attains an approximate thickness of 200 feet and holds a scanty marine fauna in which **Liorhynchus limitare** was noted but does not appear in the only collection made.

Lower Selinsgrove Limestone.

The **Lower Selinsgrove Limestone** of White[13], coming in the lower half of the Marcellus Series and separating the upper shale from the Lower Selinsgrove Shale, was noted at several points in Pocahontas County. It is predominantly a dark calcareous shale containing dark-blue and thin fossiliferous limestone, attaining a thickness of approximately 100 feet along Deer Creek one mile southwest of Green Bank.

The **Lower Selinsgrove Shale** of White[13], coming below the Lower Selinsgrove Limestone, is also present in Pocahontas County, being a black, fissile, and carbonaceous shale, containing Marcellus and Onondaga fauna, and often holding numerous large concretions. This member, occurring as it does immediately above the Oriskany Series, is generally found mashed and squeezed, standing at steep dips, so that its true thickness is difficult to obtain, but it would seem to occupy an interval varying from 50 to 100 feet.

ECONOMIC ASPECTS, MARCELLUS SERIES.

The Marcellus Series weathers into a gray plastic clay soil which in itself is poor for cultivation, but is generally enriched by a wash from the adjoining hills, and locally by the presence of the Lower Selinsgrove Limestone. The local limestones, while comparatively pure, are too thin for commercial purposes, their greatest value being in additional lime to the soil in situ.

The Marcellus shales have a comparatively high carbon content from which various petroleum products may be distilled. The shales of this series burned for several days in the vicinity of Green Bank. No prospecting was done for oil shales in Pocahontas County, in the preparation of this report, but a sample was collected by the writer from this series in Hardy County, and distilled in the laboratory of Chemical Engineering at West Virginia University, which showed the presence of both oil and gas in these shales. Their value for this purpose will need to have further investigation at some future date.

LOWER DEVONIAN ROCKS.

GENERAL STATEMENT

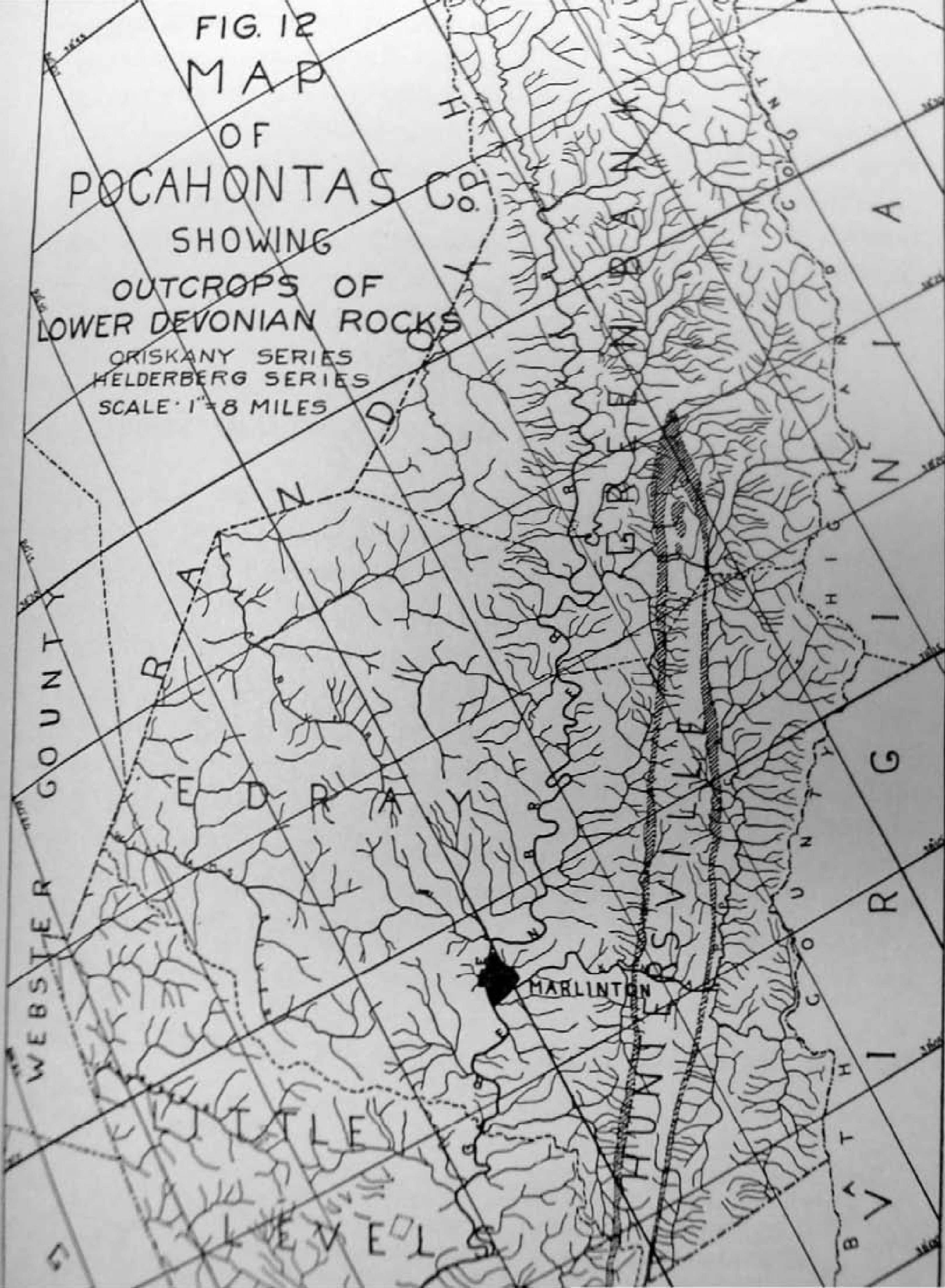

FIG. 12

MAP
OF
POCAHONTAS CO.
SHOWING
OUTCROPS OF
LOWER DEVONIAN ROCKS
ORISKANY SERIES
HELDERBERG SERIES
SCALE: 1" = 8 MILES

have an approximate thickness of 400 feet. In this area a succession of chert beds that is not present in northeastern counties of West Virginia makes its appearance immediately above the sandstone member (Ridgeley). A discussion of these beds will appear in succeeding pages.

Figure 12, prepared by the writer, with drafting by George W. Grow, shows the outcrops of the Lower Devonian Rocks, while on Map II the same series are shown in much greater detail and on a larger scale.

ORISKANY SERIES.

GENERAL ACCOUNT AND SECTION, ORISKANY SERIES.

The Oriskany Series, which forms the upper subdivision of the Lower Devonian Rocks, and lies beneath the Marcellus Series of the Middle Devonian, is represented in Pocahontas County by a gray or brown, massive, coarse, ferruginous, and marine-fossil-bearing sandstone at the base, and by a succession of yellow, gray, and dark cherty beds at the top, that also contain a marine fauna of Oriskany age. The sandstone member generally contains in its upper portion a bed of small quartz pebbles which resemble rice or wheat grains. This bed has often been called the "Wheat Grain" Conglomerate. At some localities it contains pockets of iron ore with traces of manganese. The following section for the county has been compiled:

General Section of Oriskany Series for Pocahontas County.

	Thickness. Feet.	Total. Feet.
Oriskany Series		
Chert, Huntersville, yellow, gray to black, sandy, with occasional streaks of green phosphatic sandstone; contains marine fossils; **Leptaena rhomboidalis** and **Orbiculoidea ampla,** common; breaks down into		

Springs in Pocahontas County.

	Location.	District.	Geologic Horizon.	Own
	Minnehaha Springs	Huntersville	Marcellus-Oriskany	W. A. H. Ho
	Browns Mt., 0.7 mi. N. W. of Mt. Tabor School	Huntersville	Helderberg-Bossardville	Peter McCar
	State road 3 mi. S. E. of Huntersville	Huntersville	Helderberg-Bossardville	S. P. Curry
	0.5 mi. W. of Frost	Huntersville	Helderberg	Sherman Gib
	0.8 mi. S. E. of Dunmore	Greenbank	Bossardville	Reece Prtcha
	1 mi. W. of Durbin	Greenbank	Basal Greenbrier Ls.	Jacob Slaven
	Onoto	Edray	Maccrady-Greenbrier Ls. Contact	F. R. Hunte others
	0.2 mi. N. of Edray	Edray	Basal Greenbrier Ls.	Lee Price
	Linwood	Edray	Greenbrier Ls.	Eugene Gat
	1 mi. S. of Onoto	Edray	Basal Greenbrier Ls.	E. R. Sharp
	1½ mi. W. of Onoto	Edray	Basal Greenbrier Ls.	Porter Shar
	ampbelltown	Edray	Basal Greenbrier Ls.	James A. S
pring	Head of Sharp Run	Edray	Maccrady Series	Adam Moor
	McClintock Run	Little Levels	Basal Greenbrier Ls.	Withrow M
	Mill Point	Little Levels	Basal Greenbrier Ls.	Tom Beard
	E. end of Droop Mt.	Little Levels	Mauch Chunk Series	J. Cutlip's

in Pocahontas County are located at the village of Minnehaha Springs. These springs emerge from the ground at two or more points through the Marcellus Shale, but near the contact with the Oriskany Sandstone which is dipping rapidly to the southeast and at an elevation of 2330′ B. At the present time a summer resort is located here, called the Minnehaha Springs Inn, including a hotel, swimming pool, and various forms of recreation. According to the literature furnished by the present owner and manager, W. A. H. Hobbs, the spring flows 1,500,000 gallons per 24 hours with a temperature of 72° Fahrenheit. The swimming pool, which is of concrete construction, is constantly being filled with the overflow from the main spring. The following analysis of the water from this spring as furnished by the present manager is as follows:

Analysis by D. C. Oudshoorn, Chemist, West Virginia University.

	Parts per million.
Free Ammonia	0.03
Albuminoid Ammonia	None
Nitrogen as Nitrites	None
Nitrogen as Nitrates	Trace
Required Oxygen	0.12
Silica (SiO_2)	6.50
Calcium Carbonate ($CaCO_3$)	88.84
Magnesium Carbonate ($MgCO_3$)	22.36
Iron Oxide (Fe_2O_3)	0.02
Aluminum Oxide (Al_2O_3)	0.09
Calcium Sulphate ($CaSO_4$)	12.45
Sodium Chloride ($NaCl$)	19.63
Potassium Chloride (KCl)	3.09
Loss on Ignition	10.05
Total solids	163.18

It is a mineral water of very high purity. A sample of this water was taken by the writer and analyzed by B. B. Kaplan, Chemist of the

General Statement.

The older limestones of Pocahontas County, including the basal Devonian and Silurian limestones, are of less extent than those of the Mississippian but of considerable local importance. These lie entirely east of the Greenbrier River and may be seen along the Beaver Lick-Browns-Michael Mountain area, their exposure being due to erosion along the Browns Mountain Anticline.

In the Devonian Period the thin Lower Selinsgrove Limestone occurs near the base of the Marcellus Series, and the Helderberg Series, marking the lowest formation of the Devonian, is composed largely of siliceous limestone. In the Silurian Period large deposits of high-grade limestone comprise the upper portion, including the Salina Series. Because of the general inaccessibility of these beds their importance as a commercial product is less than that of the Greenbrier Limestone of the Mississippian Period, but of considerable importance locally to add lime to the soil and as a source of lime for local burning for agricultural purposes. Furthermore they may be used advantageously as crushed limestone for road building purposes. The following limestones of the Devonian and Silurian Periods, in descending stratigraphic order, are deserving of economic discussion:

Devonian Period:
- Marcellus Series
  - Lower Selinsgrove

Silurian Period:
- Salina Series
- Niagara Series.

Lower Selinsgrove Limestone.

The **Lower Selinsgrove Limestone,** previously described under the discussion of the Marcellus Series, is composed of

Fork of the Greenbrier River in the northern part of the county.

In the Devonian Period the shales of the Catskill Series correspond favorably with those of the Mauch Chunk and are located in most cases along the Chesapeake and Ohio Railway so that they are easily available. The shales of the Chemung and Portage Series are interbedded with flaggy sandstones so that they offer little inducement, while the black Genesee and Marcellus Shales, lower down, contain so much organic matter that their shrinkage would be too great.

In the Silurian Period shales occur in the Clinton and Red Medina Series. In some cases the former by careful selection might be successfully used for building brick or tile, but their exposures are generally inaccessible so that the better located deposits would naturally outrank them in importance.

Fire Clay.

The true fire clays that have a quality of resisting high furnace temperatures are not known to occur in the county. It is possible that in the western portion of the county some of these clays may be associated with the coals but all clays associated with the coals are not fire clays, so that only further investigation will definitely determine their presence. Even if present, however, their general inaccessibility would prevent their use in the near future.

BUILDING STONE.

QUARRIES.

In Chapters VI-XI inclusive, dealing with stratigraphy the sandstones have been described, with attention called to those which have been quarried or which are suitable for masonry construction; and at the beginning of Chapter XIV the limestone quarries have been noted. Very seldom have for building purposes, the

The sandstones of the county, as described in Part II of this report, vary from thin flaggy and shaly beds that are of no value as building stone to massive ledges 50 to 75 feet in thickness that can be worked into any desired shape. In the Pottsville Series there are several coarse, gray to white sandstones that can be used locally for dimension stone as the needs arise. In the Mauch Chunk Series many of the sandstones are often shaly and lenticular, while others are of massive and durable character with a pleasing texture. In the Greenbrier Series there are no sandstones suitable for building stone but some of the limestones might be successfully used for such purposes. The Union or "Marble" member will be discussed more in detail on the following pages. The Maccrady Series offers no stone durable enough for construction material, but the Broad Ford Sandstone member of the underlying Pocono often attains a character suitable for dimension stone. As previously noted it has been quarried quite extensively at Marlinton and at many other points along the Greenbrier River for use in bridge abutments, building foundations and steps, where durability and abrasive resistance are important.

In the Devonian Period the Catskill Series contains numerous ledges of sandstone that are often shaly and lenticular but occasionally quite massive and durable with colors of brown and red. In the Chemung and Portage Series the sandstones are generally flaggy but often attain beds of considerable thickness. These beds weather out, breaking along the joint-planes into rectangular shapes of various sizes and with very smooth faces, so that further shaping is unnecessary. The colors vary from gray to brown to green and buff. That a market could be found for these flags is quite likely since structures built from them are not only pleasing in appearance but very durable. Several of the Universities of central New York have constructed some of their finest buildings from stone of similar character.

persistent but in this area it is generally unfit for masonry.

In the Silurian Period there are heavy sandstones in the Clinton Series, two of which are quartzitic and very durable but of such a character as to be very difficult to work, while a third, or "Iron Sandstone", is of a red color, very durable and often weathers into rectangular blocks so that further shaping is seldom necessary. Where these beds are not already broken by gravity, it is very difficult to shape them. The White Medina Sandstone is massive and generally quite quartzitic, like those of the Clinton, and it is very difficult to work into any desirable shapes. In the Red Medina the sandstones are generally too shaly and irregular to be of any value.

POCAHONTAS "MARBLE"[2]

In the vicinity of Hillsboro, (See Figure 20-A), the Union member, occurring near the top of the Greenbrier Series, has attained a character that classifies it, to the trade, as a grade of marble. This member, which is highly fossiliferous, contains such marine life as blastoids **(Pentremites)**, crinoids, brachiopods, corals, gastropods, and bryozoa **(Archimedes)**. Along with this abundance of marine life are millions of minute concretions resembling fish roe which are called oolite. Either at the time of deposition or by later infiltration from circulating waters (probably the former) sufficient coloring was carried in to give it a pleasing appearance to the eye, more especially when polished. These deposits vary in color from red to maroon to a pinkish tinge and from that to the various shades of gray. This marble phase varies from 25 to 40 feet in thickness, being red or maroon, highly fossiliferous and oolitic at the top, and blending into a light fossiliferous oolite, with the various shades of gray, at the base. This horizon will produce stone suitable for ornamental purposes.

Above the red is a 20-foot highly fossiliferous, finegrained, gray limestone that could also be used as a building concealed interval of 35 fossils; location, 1.3 miles northwest of Edray; elevation, 3010'; stratigraphy, No. 37 of Edray Section, p. 94; collector, P. H. Price; description, pp. 374-5.

18. Mauch Chunk Series; Glenray Limestone; marine fossils; location, along new State road (No. 24) 1.3 miles northwest of Edray; elevation, 3040'; stratigraphy, No. 33 of Edray Section, p. 94; collector, P. H. Price; description, p. 374.

19. Greenbrier Series; Alderson Limestone (top); marine fossils; location, along new State road (No. 24) 1 mile northwest of Edray; elevation, 2970'; stratigraphy, No. 40 of Edray Section, p. 94; collector, P. H. Price; description, p. 375.

20. Marcellus Series; Onondaga Limestone; marine fossils; location, along highway 1 mile northwest of Frost or just east of Cove Hill School; elevation, 2625'; collector, P. H. Price; description, p. 397.

21. Pocono Series; Broad Ford Sandstone; marine fossils; location, along road to Linwood 1.5 miles west of Clover Lick; elevation, 2365'; collector, P. H. Price; description, pp. 380-1.

22. Pocono Series; Broad Ford Sandstone; marine fossils; location, on road to Kee Flats 1 mile southwest of Marlinton; elevation, 2300'; stratigraphy, No. 6 of Kee Flats Section, p. 97; collector, P. H. Price; description, p. 381.

23. Mauch Chunk Series; Reynolds Limestone; marine fossils; location, along second-class road in sharp curve 1 mile south of Spruce Flats School; elevation, 3100'; stratigraphy, Spruce Flats Section; collector, P. H. Price; description, p. 373.

24. Greenbrier Series; Alderson Limestone; marine fossils; location, along Staunton and Parkersburg pike 3 miles northwest of Durbin; elevation, 3375'; stratigraphy No. 22 of Durbin Section, p. 117; collector, P. H. Price; description, pp. 375-6.

25. Niagara Series; marine fossils; location, 1.2 miles southeast of Dilleys Mill and 0.3 mile northeast of Bethel School; elevation, 2775'; collector, P. H. Price; description, p. 401.

26. Chemung Series; upper portion; marine with some plant fossils; location, along Pocahontas-Pendleton County line, 1.5 miles southeast of The Pigs Ear; elevation, 3950'; collector, P. H. Price; description, pp. 387-8.

27. Hamilton Series; marine fossils; location, road ballast at Huntersville bridge; collector, P. H. Price; description, pp. 396-7.

28. Chemung Series; Valley Head Sandstone; plant fossils; location, along Knapp Creek, 4.5 miles southeast of Marlinton; elevation, 2200'; stratigraphy, Knapp Creek Section, p. 106; collector. P. H. Price; description, pp. 388-9.

29. Chemung Series; Valley Head Sandstone; plant fossils; location, along Knapp Creek, 4.5 miles southeast of Marlinton; elevation, 2200'; stratigraphy, Knapp Creek Section, p. 106; collector, P. H. Price; description, pp. 388-9.

30. Chemung Series; plant fossils; location, Laurel Creek, 0.2 mile west of Rimel; elevation, 2440'; collector, P. H. Price; description, p. 389.

twigs and plants; location, 0.6 mile north

Distribution of Collections by Geologic Formations.

Pennsylvanian System.
- Pottsville Series.
  - New River Group, No. 36.

Mississippian System.
- Mauch Chunk Series.
  - Hinton Group, No. 60.
  - Bluefield Group.
    - Reynolds, Nos. 9, 23, 33, 38, 56.
    - Glenray, No. 18.
    - Lillydale Shale, No. 17.
- Greenbrier Series.
  - Alderson, Nos. 19, 24, 55.
  - Greenville Shale, Nos. 7, 8, 8A.
  - Patton, No. 6.
  - Hillsdale, No. 32.
- Pocono Series.
  - Broad Ford, Nos. 10, 21, 22.
  - Sunbury, Nos. 39, 44, 46, 47, 59.
  - Berea, No. 48.

Devonian System.
- Upper Devonian.
  - Catskill Series.
    - Saxton, Nos. 40, 45, 62.
  - Chemung Series, Nos. 5, 26, 28, 29, 30, 35, 42, 50, 52.
  - Portage Series, Nos. 1, 31, 37, 41, 43.
  - Genesee Series, Nos. 11, 14, 15, 16, 63.
- Middle Devonian.
  - Hamilton Series, Nos. 13, 27.
  - Marcellus Series.
    - Onondaga, No. 20.
- Lower Devonian.
  - Oriskany Series.
    - Huntersville Chert, Nos. 53, 64.
  - Helderberg Series.
    - Keyser, Nos. 2, 54.

Silurian System.
- Salina Series.
  - Bossardville, Nos. 4A, 49, 51.
- Niagara Series.
  - McKenzie, Nos. 12, 25.
- Clinton Series.
  - Rochester (of Maryland), No.

of **Ambocoelia virginiana**, a form that is found in both the Marcellus and the Hamilton. With these are a few **Chonetes coronatus** and **Spirifer consobrinus**, both of which are found in the Hamilton only.

MARCELLUS SERIES.

Onondaga.

No. 20.—Location: Just east of Cove Hill School, one mile northwest of Frost, at elevation of 2625 feet.

Matrix: A dark, argillaceous, non-calcareous shale, with considerable limonite in the partings.

Fossils:

Anoplotheca acutiplicata
Ambocoelia virginiana
Buchiola halli
Platyostoma sp.
Styliolina fissurella
Tentaculites sp.

Comment: **Anoplotheca acutiplicata** is distinctive of the Onondaga, or lowest division of the Marcellus. It is here represented by numerous compressed forms. **Ambocoelia virginiana**, **Buchiola halli**, and **Styliolina fissurella** are all reported from both the Marcellus and the Hamilton.

ORISKANY SERIES.

Huntersville Chert.

No. 53.—Location: Half a mile northwest of Burr Post-Office, at elevation of 2750 feet.

Matrix: The matrix is of two types. The first is light-colored, almost white, fine-grained sandstone, with outside weathered to a light-brown, and in places stained by iron of **Ambocoelia virginiana**, a form that is found in both the Marcellus and the Hamilton. With these are a few **Chonetes coronatus** and **Spirifer consobrinus**, both of which are found in the Hamilton only.

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ORISKANY SERIES.

Huntersville Chert.

No. 53.—Location: Half a mile northwest of Burr Post-Office, at elevation of 2750 feet.

Matrix: The matrix is of two types. The first is light-colored, almost white, fine-grained sandstone, with outside weathered to a light-brown, and in places stained by iron

Spirifer intermedius.

The chert contains the following:

Orbiculoidea ampla
Leptaena rhomboidalis var. ventricosa
Schuchertella woolworthana
Diaphorostoma ventricosum
Diaphorostoma depressum.

Comment: These are all fossils of the Oriskany. Parts of both valves of **Orbiculoidea ampla** are nicely preserved in the chert.

No. 64.—Location: Top of quarry, Knapp Creek, 1.5 miles southwest of Frost.

Matrix: A brittle, greenish, shaly, non-calcareous sandstone, breaking irregularly, stained brownish somewhat from oxidation of abundant ferrous iron.

Fossils:

Orbiculoidea ampla.

HELDERBERG SERIES.

Keyser.

No. 2.—Location: Along State road (No. 43), 0.4 mile southwest of Huntersville, at elevation of 2260 feet.

Matrix: A dark, grayish-brown, fine-grained, arenaceous limestone or calcareous sandstone containing ostracods, indefinite black flakes and angular fragments of brachiopods. Weathering has in places brought to light a distinct lamination.

Fossils:

Gastropod (small, flat-coiled)
Leperditia sp.
Kloedenia pennsylvanica ?

Comment: The horizon is an ostracod horizon. The pres-

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State, and probably as much more (200-250 million feet) is daily wasted through unplugged wells, leaking joints, and from producing oil wells. This estimate would make the quantity of natural gas daily coming to the surface in West Virginia, about one billion cubic feet, or the equivalent in heating power of one million bushels of coal—(40,000 tons) daily—14,600,000 tons annually or more than half of the State's annual production of coal.

All of this gas that is piped out of the State is sold at a rate of not less than 25 cents per 1,000 feet for domestic purposes, and 10 cents per 1,000 feet for manufacturing uses, while that taken to distant points, like Toledo, Cleveland, etc., is sold at 40 to 50 cents per 1,000 feet, hence if we value the gas produced in the State at only 10 cents per 1,000 feet, on the basis of one billion feet of daily production, it would amount to $100,000 per day, one-fourth of which is wasted without accomplishing any useful purpose whatever.

Quite recently there has been a general awakening to the enormity of this inexcusable waste of the best fuel in the world, and hence it is to be hoped that the State Legislature will, at its next session, take steps to prevent the same.

Methods of Transportation.

As is well known, natural gas exists in porous rocks under a pressure, proportioned to the depth of its reservoir below the surface of the valleys. This ratio of increase in pressure with depth is in about the same proportion as the weight of a column of water would increase with its length, so that at depths of 2,000 feet, 600 to 900 pounds of pressure to the square inch is developed when the gas in a new field is shut in, and for depths of 2,500 to 3,500 feet, pressures of 1,000 to 1,500 pounds are developed under like conditions.

This "rock pressure" as it is termed is sufficient of itself to transport the gas in large quantity by its own expansive energy from central West Virginia (Lewis county) to Toledo and Cleveland, distances of nearly 200 miles, so long as the "rock pressure" in the wells does not decrease below 500 to 600 pounds to the square inch. But in that particular gas horizon will gradually decline, until its effective pressure to deliver gas at the end of a long pipe line would be lost entirely. To meet this contingency, the Philadelphia, Hope, and Carnegie Gas Cos. are installing large pumping stations in Wetzel county, where the gas flows from the wells to the pumps under a low pressure, and is then compressed by immense engines to about 600 pounds to the square inch before it enters the mains for transportation beyond the boundaries of the State.

The quantity of gas which any pipe line will transport, either under the natural pressure of the gas, or the artificial pressure created by pumps, depends upon many factors the relations of which have been investigated and skillfully worked out by Prof. S. W. Robinson, of the Ohio State University, and published in Vol. VI, of the Ohio Geological Survey. The diameter of the pipe, the length of the line, the pressure at the intake end, all enter into the calculation, while the number of angles or abrupt bends in the line all of which produce friction and retard the flow of gas are also large factors in the transportation of gas.

Mr. F. H. Oliphant has recently treated the subject of gas well measurement, and gas transportation quite thoroughly as based upon Prof. Robinson's formulae, and the following statements are quoted from his Report to the U. S. Geological Survey on the production of natural gas for 1902, pages 18-27:

Natural Gas Measurement.

"Originally the individual gas consumer was charged according to the size of the orifice used, through which at a known pressure, usually from 4 to 8 ounces to the square inch, a certain quantity of natural gas would pass. The consumer was allowed to use, if he so desired, all the gas that would pass through this orifice, for which a fixed price was paid. There was no inducement offered by the natural gas company to have the consumer use it in an economical manner.

Subsequently the meter was introduced, often to the general satisfaction of both of the parties interested.

under great pressure, a meter that will properly record the amount is weighty and expensive. To reduce the cost the proportional meter is in many instances used, in which a proportionately small amount is diverted to a tally meter controlled by a valve which equalizes the pressure. This tally meter is generally provided with a scale, which records the gross amount passed.

Natural gas is usually sold to the consumer by the cubic foot at a standard pressure of 4 ounces to the square inch, or 36 pounds to the square foot at a temperature of 60 degrees F. In many instances it is convenient to dispose of the gas at higher pressures, and then it is necessary to construct meters of proportional strength. The mean pressure of the atmosphere for the elevation at which most of the natural gas is sold is assumed to be 14.4 pounds to the square inch. In order to arrive at the correct number of feet when the gas is measured at a pressure greater than four ounces, the following formula will be found to be convenient. Usually no correction is made for change in temperature.

Formula for Measuring the Quantity of Natural Gas When Measured Above Normal Pressure.

$$Q=q\frac{p+h}{h+.25}$$

In which

Q is the cubic feet required.
q is the cubic feet shown by the meter.
p is the gauge pressure in pounds.
h is the atmospheric pressure of 14.4 pounds.
0.25 is 4-ounce pressure reduced to pounds.

By substituting the known values in the above it becomes

$$Q=q\,\frac{p+14.4}{14.65}$$

For example: Suppose the meter or "q" reads 1,000 cubic feet, and the pressure, "p" shows 32½ pounds to the square inch; required, to find the quantity of gas, then

$$Q=1{,}000\,\frac{32.5+14.4}{14.65}=3.2014\times1{,}000=3{,}301.4$$

The result is therefore 3,201.4 cubic feet at the standard pressure of 4 ounces to the square inch. If the gas is measured at atmospheric pressure, th necessary to form a capacious reservoir for a large gas well, would take place most readily along the anticlinals where the tension in bending would be greatest.

"The geological horizon that furnishes the best gas reservoir in western Pennsylvania seems to be identical with the first Venango oil sand, and hense is one of the Catskill conglomerates. This is the gas rock at Murrysville, Tarentum, Washington, Wellsburg, and many other points. Some large gas wells have been obtained in the Sub-carboniferous sandstone (Pocono,) however, and others down in the third Venango oil sand. (Chemung.)

"In Ohio, gas flows of considerable size have been obtained deep down in the Cincinnati limestone, while in West Virginia they have been found in the Pottsville conglomerate; hence natural gas, like oil, has a wide range through the geological column, though it is a significant fact that it is most abundant above the black slates of the Devonian."

The views expressed in this paper were criticized by several geologists, but they were as warmly espoused and championed by others, so that the battle for the essential truth of the anti-clinal, or structural theory of the occurrence of oil and gas in commercial quantities, was soon won.

The Anticlinal or Structural Theory Not New.

This *structural theory* for the occurrence of petroleum and natural gas, arrived at independently by myself on the suggestion of Mr. Earseman, proved to be not new, but had long before been proposed by other geologists, though none of them with the exception of Andrews, and Minshall, had ever applied its principles in a practical way.

Dr. T. Sterry Hunt, the late eminent Canadian geologist, was probably the first to recognize the principles involved in the *anticlinal theory,* having published a paper on the subject in the *Canadian Naturalist*, as early as 1859, and another in the *American Journal of Science and Arts* for March, 1863.

The late Prof. E. B. Andrews, of Marietta, Ohio, also appears to have reached the same conclusions independently of Dr. Hunt, for in an article in the *American Journal of Science,* dated Marietta, May 20th, 1861, descriptive of the "Oil Break" view as Andrews, concerning the West Virginia "Oil Break" in a series of articles published in the summer of 1881.

Prof. H. Hoefer, the distinguished geologist of Leoben, Austria, also appears to have formulated the same conclusions from a study of the Pennsylvania oil fields in 1876, and published the elements of the anticlinal theory, in his book on "The Petroleum Industry of North America," pages 77-80, without any knowledge of the previous publications of Hunt and Andrews, while Newberry, Stevenson, and probably others had advocated the influence of *rock disturbance* as early as the '70's. Thus it appears that the theory had long ago been recognized and its essential elements published, but the practical oil men had never heard of it in a way to make any impression upon them, and the authors of the theory had made but slight attempts to apply its principles practically in the location and discovery of new oil or gas fields. This is the work which the writer has especially accomplished, and in the doing of it so enforced the lessons of geology upon the minds of the men engaged in the practical work of drilling for oil, that the acceptance of the structural theory is now universal among them, as well as among geologists. In this work the writer has been ably assisted by the late Dr. Edward Orton, State Geologist of Ohio, whose acute mind and facile pen have done much to popularize and enforce the geological claims of the anticlinal theory.

The geologists of Indiana have also contributed much to compel belief in the structural theory of oil and gas accumulation.

On the continent of Europe, and in Russia no other theory has any followers whatever, due largely to the work of Hœfer, Sjogren, and other geologists. No one can visit Baku, Grozny, Gallicia, and other oil fields of the old world, and see the great anticlinals which accompany every important deposit of petroleum, without concluding that *rock disturbance* is the important factor in such accumulations. It was the numerous

Prof. Andrews, in 1861, of the agency of *structure* in oil and gas accumulation. Guided by this principle, the writer pointed out and located all the great oil pools of West Virginia, for a Pittsburg syndicate in 1884 and 1885, long before the drill finally demonstrated the correctness of his conclusions. The detailed account of how one of these great pools was subsequently located and developed, 35 miles distant from any oil production at the time, has been told by the writer in an article entitled, “The Mannington Oil Field and the History of Its Development,” published in the Bulletin of the Geological Society of America, Vol. 3, pages 187- 216, April 15th 1892, and the following quotations therefrom will give the reader a definite idea of the practical application of the principles embodied in the anticlinal theory in the discovery of an oil or gas pool:

> “The Mannington oil field was developed by myself and associates, and as its location was made from purely scientific deductions illustrative of certain theories concerning oil and gas accumulation which I have taught for several years, a brief history of these theories and their application in the discovery of the Mannington field may not be without interest to geologists; and this must excuse much that is personal to myself in connection therewith.
>
> “As is well known, it was formerly a popular saying among practical oil men that “Geology has never filled an oil tank;” and to such a low estate had oil geology fallen that a prominent producer of oil and gas, disgusted with geology and geologists, was once heard to remark that if he wanted to make sure of a dry hole he would employ a geologist to select the location. It has been my pleasant task during the last eight years to assist in removing this stigma from our profession, so that with the able and valuable assistance of Ohio's distinguished geologist, Professor Orton, Dr. Phinney, of Indiana, and others the battle against popular as well as scientific prejudice has been fought and won and this long standing reproach to geology in great part removed.
>
> “The essential principles involved in the “anticlinal theory,” have been very forcibly and graphically set forth by Professor Edward Orton, whose philosophic mind and skillful hand have grappled with and unraveled so many tangled threads of geologic history. Grasping at once the truth of the “anticlinal theory,” he applied its principles in a striking and beautiful way to the

oil, a little gas, a little water, a little of everything, and not much of anything;'' while if the rock reservoirs be tilted considerably, so that the small quantities of oil, gas, and water in all sedimentary beds can rearrange themselves within the rocks in the order of their specific gravities, then and then only can commercial quantities of each accumulate, provided the reservoir and cover are good. The anticlinal waves which traverse the great Appalachian plateau westward from the Alleghanies and practically parallel to these mountains present just such relief as the theory requires in the New York, Pennsylvania, southern Ohio, and West Virginia oil and gas fields, while the more ancient flexures in northern Ohio and Indiana account for the large accumulations of oil and gas in the Trenton limestone of those states. The Florence (Colorado) and other oil fields in the far western states and territories have this tilted rock structure, and the same relief is plain in the Canadian oil and gas fields, according to Selwyn; while Tschernyschew, Sjogren, and other geologists who have studied the foreign oil fields, report an identical geological structure there.

''This theory, so simple and consonant with well known physical laws, as well as so harmonious with the facts of geology, was heartily welcomed by most of the oil and gas operators, and by nearly all geologists that have given any thought to the matter, as a satisfactory solution of the geologic problem connected with oil and gas accumulation. A few have attempted to relegate the great principle of relief to a subordinate position, but the facts have pointed so conclusively in the other direction that opposition has been silenced at least, whether convinced or otherwise.

''Guided by this theory I located in 1884 the important gas and oil field near Washington, Pennsylvania; also the Grapeville gas field along that great arch of the same name in Westmoreland county; and the Belleveron field on the Monongahela river. On the same theory I located and mapped out, for Mr. J. M. Guffey, the celebrated Taylortown oil field of Washington county, nine months before the drill demonstrated the truth of my conclusions. And right here on this Mannington-Mount Morris belt a derrick was built to bore for oil on one of my locations at Fairview more than five years before the drill finally proved that my location was immediately over one of the richest pools in the country, and before the drill had shown that there was any oil in this portion of West Virginia. These are only a few of the positive fruits of the theory to which we can point; the negative results in condemning immense areas of both oil and gas being even more important in preventing unnecessary expenditure and waste of capital where a search for either gas or oil would have certainly been in vain.

''My working hypothesis was that since the gas pressure is due face of a lake or a chain of small lakes, if the rock reservoir should not be equally porous everywhere along the strike. Hence, if my theory is true, it would only be necessary to follow the strike of any particular coal bed, limestone, or other stratum outcropping where the oil was actually developed in order to trace the course of the oil belt upon the surface, and thus to determine with approximate accuracy, many miles in advance of the drill, the location and width of such possible oil territory. Very fortunately for my purpose, two persistent coals, the Waynesburg and the Washington beds, cropped to the surface at Mount Morris, the first well finished there by Mr. E. M. Hukill, in October, 1886, starting immediately on top of the Waynesburg seam.

"My first work was to determine the tide elevation of these coal beds, especially the Waynesburg, with reference to oil, gas and salt water as developed by the Mount Morris borings. For this purpose one of my associates, Professor T. M. Jackson, then Professor of Civil Engineering at the West Virginia University, ran a line of levels from the Monongahela river (using a Baltimore and Ohio railway datum) out to the oil field, and made a complete survey and map of the twenty or more wells that had been drilled at that time (February, 1889) in and about the village of Mount Morris. He also obtained the elevations of the coal beds at every possible point. From the data thus acquired it was learned that wherever the Waynesburg coal had an elevation of 950 feet above tide, gas, and not oil was found, and that where it had dipped down below 870 feet, salt water was a certainty—in the Mount Morris region at least. As the Washington Coal is 155 feet above the Waynesburg bed, the gas and saltwater limits were found to be 1,105 and 1,025 feet above tide, respectively, when referred to the Washington bed as a datum line.

"With these facts in hand, it was only a question of correct identification, or tracing of coal beds, and a simple matter of leveling, in order to follow the strike of the surface rocks at least, for a hundred miles or more. But the query arose to me, "Suppose the surface rocks do not lie parallel to the oil sand, then where will the oil belt be found?" The interval between these coal beds and the oil sand might either thin away considerably or thicken up an equal amount in passing southward from Mount Morris. Of course, if either of these things should happen, the strike of the oil sand would not run with the strike of the surface rocks, but would gradually veer away from the latter either eastward or westward, depending upon whether the intervening measures should thicken up or thin away. To meet any such possible contingencies, the territory within which an elevation of 800 instead of 870 feet (the western limit of oil at the north.)

"In following the strike line from Mount Morris to Mannington its direction was found to vary greatly. For the first five or six miles between Mount Morris and Dolls run the strike was about S. 30 degrees W.; but toward the head of Dolls run, the line turned rapidly westward, making a great curve or elbow and running westward past the village of Fairview, from which, with many curves and sinuosities, it crossed successively Plum run, Mods run and Buffalo creek at Mannington, on a general course of S. 45 degrees W., but varying from this 10 degrees to 15 degrees either way in certain localities. The strike line carried on southward from Mannington passed into Harrison county through the villages of Pleasantville and Grangeville.

"This course which I thus mapped out for the extension of the Mount Morris oil belt was so crooked and passed so much farther westward than the practical oil men had considered possible that my geological line, or hypothetical belt, furnished occasion for many jokes and gibes at my expense among the oil fraternity; and it was with the greatest difficulty and only by liberal gifts of supposed oil territory that I could induce any of them to risk their money on a purely geological theory. Finally, however, a contract to drill a test well in the vicinity of Mannington was entered into in the spring of 1889 with Mr. A. J. Montgomery, of Washington, Pennsylvania, a gentleman who had given considerable thought to geology. As this was to be a crucial test of my theory, the proper location for the test, 20 miles distant from any producing oil well, gave me no little concern, since if the well should prove a failure, oil geology would receive a fatal blow, in the eyes of practical oil men, while if successful their confidence in geology would be greatly increased and strengthened.

"The problem I had to solve was, whether the interval between the surface rocks and the oil sand would remain the same as at Mount Morris, or whether it would either thicken or thin; since, upon my theory, if I made a location at Mannington where the Waynesburg coal had an elevation of 900 feet above tide, and the interval from it to the oil sand remained the same (1,625 feet) as at Mount Morris, then if the oil rock proved open and porous a fair oil well should be found; while if, on the other hand, this interval should thin away to, say, 1,575 feet, then gas would be found, and if it should thicken up to 1,675 feet, salt water would be obtained, and this especially would be fatal to my theory, for the practical oil men were predicting that Mannington was several miles too far westward, and hence was in salt water territory. In the absence of any evidence bearing upon the subject, and rather in opposition to a general geological fact, viz.: that the sedimentary beds thin away rapidly westward from the Alleghanies, I made up my mind to take no chances on salt water in this, the first test well, and in finally a location at Mount Morris would have been in the gas belt by an elevation of 20 to 25 feet to spare.

"As the drill progressed it was found that the intervening rocks were thickening instead of thinning when compared with the Mount Morris column, and when the top of the oil sand ("Big Injun") was finally struck, the interval from it to the Waynesburg coal measured exactly 1,725 feet instead of 1,625, as at Mount Morris. Finally, on October 11, 1889, the drill penetrated the oil-bearing zone of this sand, and was immediately followed by a copious showing of oil, the result being that my theory was at once raised from the domain of conjecture to that of demonstrated fact. Thus a great victory was won for geology, since it taught the practical oil men once for all that they could not afford to disregard geological truths in their search for oil deposits.

"This thickening of the interval between the Waynesburg coal and the oil sand to the extent of 100 feet, in the distance of 25 miles from Mount Morris to Mannington, proved to have exactly the effect that I anticipated, i. e., it caused the oil belt to veer eastward until it gradually encroaches upon the territory occupied by the gas belt in the vicinity of Mount Morris; so that the western edge of the oil belt at Mannington is found where the Waynesburg coal has an altitude of 950 feet above tide, which is where the eastern edge occurs at Mount Morris, and the gas belt begins; and hence, had the first location at Mannington been made without taking into account a possible thickening, the well would have been too far westward, and a dry hole or salt water would have been the certain result. The amount of this eastward shifting of the strike of the oil sand compared with the strike of the surface rocks between Mount Morris and Mannington is something more than half a mile.

"Since this Mannington test well was drilled, about 200 others have been sunk along the belt, as previously defined by me, between Mount Morris and Mannington; and the correctness of my theoretical work has been demonstrated by the drill in opening up along this belt through Marion and Monongalia counties one of the largest and most valuable oil fields in the country. Fewer dry holes have been found along this belt than on any other oil belt known to me, not more than 5 per cent of the wells drilled within the defined limits proving totally dry.

"It is not claimed that this same chain of reasoning can be applied with lige successful results to the discovery and development of every great oil field that yet lies hidden below the surface of the Appalachian plateau, but it is believed that a correct understanding and appreciation of the principles involved and used in the discovery of the Mannington oil field cannot fail to prove most useful and helpful to both operator and geologist in limiting the expensive exploration of the drill to regions where the considerable distances, without undergoing a change in the character of its constituent elements. The individual particles of which it is composed must vary in size, and the cementing material, or lack of it, must be an ever-changing quantity. For these reasons any oil rock must be quite variable in porosity, and hence its productiveness cannot be a constant amount. Where the oil sand is a mere bed of coarse gravel or pebbles like that in the famous McDonald region of Washington county, Pennsylvania, or in the great Russian oil field, then the production of an oil well seems to be limited only by the size of the bore hole; while, on the contrary, the producing rock may become so close and compact within a few feet from a large producer as to be practically barren of oil. This fact was strikingly illustrated recently at McDonald, Pennsylvania, since at the very time the famous Mevey well number 1 was gushing oil at the rate of 15,000 barrels daily, another well was drilled through the same "Fifth sand," only 300 feet distant, and proved to be practically dry—the character of the producing rock having undergone a great change and become so close grained within such a short distance that it could not hold oil in paying quantity. If such changes as this can happen in the character of an oil rock reservoir within a few feet, much more would we expect such changes within a few miles; and thus it happens that although there appears to be a continuous deposit of oil in the Mount Morris sand, from the Pennsylvania line southward to Mannington, and for at least six miles beyond, yet the productiveness of the rock is not everywhere the same, because the character of the sand (reservoir) is not constant. This condition of affairs tends to concentrate the richest territory into pools of greater or less extent which are separated from each other by territory that is "spotted" or less productive.

When this tendency to change in the character of the sand or reservoir is carried so far as to render the rock impermeable to gas, oil or water for a considerable distance, then any oil belt must come to an end, and we need not expect it to set in again on the same strike of the rocks (though that is possible,) but rather when the stratum becomes again productive it will be found at a lower or higher level and on a different strike line, so that in this way we may have several parallel belts of oil in the same stratum, and occupying different levels with reference to their tidal elevation. Thus, there are numerous productive belts of the old Third Venango oil sand from Titusville, where it lies several hundred feet above tide, down to the southwestern corner of Pennsylvania, where it is 2,000 feet below tide. Hence the principles illustrated in this paper have a local as well as a general application—local, to enable the operator to follow the course of the oil belt when discovered; and general, to enable him to limit his search for oil territory to the localities where the

Effect of Mannington Experiment Upon Operators.

The successful outcome of the Mannington experiment converted most operators to a belief in the *structural theory* of oil and gas accumulation, and even the few who may still assert their unbelief in what they call the "anticlinal theory," make use of its principles in all their petroleum ventures; for there are no prominent operators now who do not observe very closely the *dip* and *strike* of the strata, and many of them employ expert geologists, and engineers to gather data in the fields as a guide to successful operations.

Relation of West Virginia Oil and Gas Pools to Geological Structure.

Every gas and oil pool in West Virginia illustrates and demonstrates the truth of the *structural theory*. The Sistersville field occupies the crown of a broad, low anticlinal where the relief is not sufficient to permit the separation of the gas, oil and salt water, and hence we find them all three commingled until the Big Injun Sand which holds them dips down to a level where only salt water is found. At but one or two limited areas in that great field has gas unaccompanied with oil or salt water been found, and these were (as they should be) where the sand attained its highest elevation.

The great gas district which stretches across Monongalia, Marion, Harrison, eastern Doddridge, Lewis, Upshur, Gilmer, Braxton, Calhoun and Roane counties, lies along the eastern edge of the oil fields, and therefore where the rock is elevated by anticlinal folds, down the slopes of which to the west we find such remarkable oil deposits.

The wonderful gas district of Wetzel and Tyler counties lies along the crest of a prominent arch of the rocks which passing south-westward through Kingtown, crosses the South Fork of Big Fishing Creek through Owl's Head Knob, (the greatest gas region in the country), and continuing on south-westward across Piney Fork, below that village, passes into Tyler

Bream to the "Big Moses" gas field on Indian creek, to which the Philadelphia Company of Pittsburg has laid 75 miles of 16-inch pipe line; while just east of this anticlinal down its southeastern slope lies the Piney Fork, Alva, Hardman, and other great oil deposits.

The string of oil pools along the crest and flanks of the famous "Oil Break" anticlinal from Burning Springs to Eureka, and northward into Ohio, repeats the same story in such a striking way that "he who runs may read," while the sudden termination of the oil pools south-west from this great arch, is a striking argument for the influence of *structure* in determining the occurrence of oil and gas in paying quantities.

Region Southwest From the Little Kanawha River.

Probably 300 wells have been drilled in that portion of the state between the Little Kanawha river and the Big Sandy at the Kentucky line, a distance of more than 100 miles, and yet, aside from a half dozen small oil wells in Roane county, doing from 5 to 10 barrels daily, and a few gas wells of moderate size, the only pools of either gas or oil of much commercial value, yet developed in all this long stretch of territory, are the gas pool developed by Mr. F. P. Grosscup at the head of Sandy creek in Roane county and the oil pool near Milton, in Cabell county. The fact that these two productive pools lie along the northwest slopes of the only prominent anticlinal arch which has yet been discovered in this entire region is quite suggestive and should lead the operator to make careful investigations of structural conditions in the broad area between the Ohio river, and where the rocks begin to rise rapidly along the slopes of the Milton and Sandy oil and gas pools, since in much of this region where so many unproductive wells have been drilled, the rocks appear to be practically horizontal. It is true, the untested region is large, and it may contain several good oil and gas pools, but its lack of prominent anticlinals, and other structural in the drilling of these 300 test wells give but little encouragement to the operator.

Necessary Conditions for the Existence of Oil or Gas in Underlying Strata.

The surface indications for the presence of oil or gas in any region are, then, the existence of well marked anticlinal waves, or what leads to the same results (viz., the accumulation of oil or gas in pools of merchantable value), the presence of rapid and irregular dips, giving rise to the *terrace* or warped structure of the strata. Of course these must be supplemented by the presence of porous reservoirs at a depth sufficiently great to prevent the escape of oil and gas to the surface in any considerable quantity.

Effect of Oil and Gas Escaping to the Surface.

Where such an escape does take place, we get as a result heavy lubricating oils, as in the "shallow sand" district near Petroleum, Ritchie county, in which case the overlying rocks are mostly porous sandstones, and evidently much fractured by the nearness of the great Burning Springs—Eureka uplift.

Effect of Rock Fissures Upon Oil and Gas Deposits.

When this fracturing of the strata has proceeded still further and opened out wide fissures (1 to 5 feet), as at "Ritchie Mine" on McFarland's Run, Ritchie county, W. Va., extending downward through all the strata to and below the underlying oil sands, thus permitting the escape of large quantities of oil and gas, the subsequent evaporation, and oxidation of the residual products left filling such fissures, have resulted in converting them into an asphaltic substance, resembling coal in appearance, named Grahamite, in the case of the Ritchie Mine deposit. That this was the origin of Grahamite, Albertite, Uintaite, or Gilsonite, is certain, since recent drilling near the Ritchie Mine in West Virginia has revealed a productive oil sand ("Salt Sand") at 1,500 feet below the valley, and what is most significant is the fact that only a little sure, thus showing that the rock has been *drained* in the immediate vicinity of the latter.

When Fissures are Small and Through Shale the Oil is Unaffected.

When the fissures are mere joints and through close-grained beds like shale, the escape of gas and oil to the surface appears to be largely prevented by even an hundred feet or so of such rock material, since at Cairo, Ritchie county, an oil of 35 degrees gravity is produced by the Clark Oil Company from a sand which lies less than 100 feet below the bed of North Hughes River. At Deem's Ferry, on the South Fork of the same stream, an oil of 40 degrees to 42 degrees gravity is found at a depth of only 250 feeet, and the oil at the mouth of Island run has about the same gravity at a depth of 300 feet.

Mountain Regions.

In most mountain regions, the fracturing of the strata has been carried on to such an extent that all the available stores of gas and oil that may once have existed in the beds have passed out of the original reservoirs through their defective covers, escaping into the air, and hence it is useless to drill for oil or gas to any ordinary depth in typical mountain regions.

It is barely possible that under a great thickness of close grained beds or shales the gas and petroleum originally contained in rock reservoirs so situated may still be imprisoned. No borings in mountain regions have been sunk to a depth sufficiently great (4,000-5,000 feet) to test the truth of this supposition.

The escape of the gas and all easily volatilized elements of the oil would render any remaining product so thick and viscous as to be unavailable except through mining operations as in the case of all asphaltic deposits which are only the residua of evaporated pools of petroleum. The great asphalt deposit at Trinidad is not in the crater of an extinct volcano as some geclosed so that the product cannot escape into the air, a pressure is developed inside the pipe. This pressure which increases with the depth of the oil or gas reservoir below the surface in about the same proportion as would the pressure in a column of water to the same depth, is known as "*Rock pressure,*" and is always greatest when a pool of oil or gas is first opened. When the producing capacity or volume of a well is large, the total pressure which a well will develop when shut in, is attained in a few seconds, or a minute at most, the famous Morgan well of the South Penn Oil Co., six miles southwest from Mannington, having developed a pressure of 800 pounds to the square inch inside of a three-inch pipe almost instantly. Wells with such large volume mean very open and porous reservoirs from which the gas or oil can escape with great rapidity. But a well of small volume, if completely shut in, will gradually develop the same "rock pressure," though it may be several hours or even days in attaining it, as the one with large volume, provided, both produce from the same reservoir, and are situated in the same pool.

The volume or value of a gas well is always roughly estimated from the pressure developed per minute when shut in (called its "minute pressure") and its total or "rock pressure." The ingenious method of measuring accurately the capacity of any gas well in cubic feet of product, by means of the Pitot tube adapted and modified by Prof. Robinson, of the Ohio State University, as already described, has not been used until quite recently by the gas companies operating in West Virginia, so far as known to the writer, greatly to their loss and detriment.

Cause of Rock Pressure.

There has been much speculation as to the cause of "rock pressure" in gas and oil wells, and many (including the writer) have believed it was of artesian origin, that is, due to water which has invaded the same rock from its outcrop at the surface. Prof. Edward Orton, the eminent State Geologist of Ohio, who has contributed so much to elucidate the problems connected apparently demonstrated its truth for the *Trenton Limestone* gas of Ohio, since in nearly every case the observed pressures agreed with the calculated pressure, assuming it to be of artesian origin and taking the level of Lake Erie as the surface outcrop of the Trenton Limestone. Recently, however, Prof. Orton has made some observations while studying the gas fields of New York that could not be explained upon the artesian theory, since in this case the "rock pressure" was 1500 pounds to the square inch at a depth of many hundred feet less than the theory would require, hence it breaks down as an explanation for all cases of gas and oil pressures, even if it may be the true cause in many fields, like the Trenton Rock of Ohio, Indiana, etc. In such cases like that of New York we are forced back upon the "*expansion hypothesis*," advocated long ago by Prof. Lesley, as the only theory that will explain the facts, and the same would appear to be the only theory consistent with the facts concerning the high pressures in the deep or Gordon group of oil sands in West Virginia, since nowhere in Monongalia, Marion, Wetzel, Marshall, Tyler, Doddridge or Harrison counties has any water* been found in this group, evidently because they are so deeply buried (2500-3500 feet) by overlying close grained beds that the surface waters have failed to percolate down to them, and hence in these cases there would be no water present in the oil sands to cause the artesian pressure. It is barely possible that the seeming agreement with the artesian pressure theory may be due to the long continued escape of small quantities of gas upward along small fissures and joints through the overlying strata until the pressure of expansion within the rock reservoir has been reduced to what we now find it on opening any new gas field. This appears to be Prof. Orton's explanation of the exceptional pressure found at a comparatively shallow depth in the New York field to which reference has been made. It is also possible that this may account for the apparent agreement between the pressures observed, and the calculated artesian pressures in many new gas fields, since if there should be a constant escape of gas from any pool, the rock pressure would decrease continually until the expansive force of the remaining gas just equals the resistance of its passage to the surface, and in the case of small fissures filled with water this pressure would evidently be practically the same as the weight of a column of water extending from the outcrop level of the gas reservoir. rock down to its level in the gas pool.

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*The only exception to this statement known is a single well of the Delmar Oil Co. on the Shaffer farm, southwest from Mannington, where some fresh water made its appearance in the Gordon sand, [illegible] it was due to a leak in the outer

Reservoir Gas and Shale Gas.

Dr. Orton makes a distinction between what he terms *reservoir* gas, and *shale* gas, the former including all *sand* or *limestone* strata, and the latter *shale* beds, which are mostly black. The pressure in *shale* gas is usually low and the volume small, the wells at Erie, Pa., and near Louisville, Ky., being examples of the same. So far as yet developed the West Virginia gas horizons all belong under the first or *reservoir* type, unless indeed we should include under the *shale* series, that found in the coal beds and in the deep boring near Huntington. Several examples are known in West Virginia as well as Pennsylvania, where valuable flows of gas have been obtained from coal beds. One of these was struck at Hundred, Wetzel county, W. Va., in 1886, by Messrs. Gibson and Giles, in the Pittsburg coal, at 700 feet in depth. Enough gas was found therein according to Mr. Gibson, with which to finish drilling the well through the Gordon sand, and it still furnishes a portion of the supply for the village.

Volume and Maximum Rock Pressure in Gas Wells.

Many of the great gas wells of West Virginia from the deep or *Gordon sand group* have never been tested for rock pressures when the pools in which they are situated

The Thomas Cunningham No. 1, of the South Penn Oil Company in Wetzel county, was one of the very large wells in the Gordon group, and on July 1st, 1898, after it had been completed nearly a year, and had blown into the air several months before it was possible to shut it in, the rock pressure was still 1,200 pounds to the square inch.

The W. J. McCoy well in Greene district, Wetzel county, is also another very large well drilled by the same company. Mr. Wm. S. Edwards of Mannington, formerly Superintendent of the South Penn Oil Co., reports that the McCoy gas well showed a pressure of 1,075 pounds in one minute in 5 3-16-inch casing, which was the limit of the test. This well has a depth of about 2,800 feet, and the Cunningham the same, as both produce from the *"Stray"* immediately above what is called the *"Gordon sand"* in Wetzel.

The Abe Shriver well No. 1 in Battelle district, Monongalia county, drilled by the South Penn Oil Co., gave a *rock pressure* of 1,200 pounds (the limit of the gauge) on a one-minute test in 3-inch tubing. The Pittsburg coal was struck at 780 feet in this well, and the gas in the Gordon, or Flat Run sand at 3,007 feet.

Mr. John Worthington, of the South Penn Co., believes that the largest gas well both in volume and rock pressure ever discovered in West Virginia or any other state, is the E. C. Morgan well No. 1, drilled by the South Penn Co., six miles southwest from Mannington, Marion county. The top of the gas sand in the Morgan well was struck at 3,052 feet, the *Pittsburg coal* having been passed at 890 feet, thus giving the same interval (2,162 feet) below the latter stratum as the *Gordon "Stray"* or *Campbell's Run oil sand* occupies on Campbell's Run, Marion county, Miracle Run, Highland, and other regions in Monongalia county, and hence this gas is possibly from the same horizon as the great wells in Wetzel county to the west, though the interval from the Pittsburg coal to the gas sand the drilling tools weighing several thousand pounds, were lifted from the bottom of the well, and blown above the top of the derrick, through 6⅝-inch casing, more than 100 feet into the air, according to Mr. Worthington. The well defied all the usual methods of procedure in shutting in large gas wells, and only after three months of uninterrupted work, was it finally conquered by the ingenuity of Messrs. Edwards and Worthington, and the men whom they directed. The 3 inch tubing could not be inserted in the 6⅝-inch casing in the customary manner, but required the pull of "block and tackle" to force it into the well. Then when the proper depth (2270 feet) had been reached, where it was decided to set the rubber packer, it would not "take hold," and on withdrawing the tubing no *rubber* was visible, the fine sand and pebbles having been blown by the gas against it with such force as to destroy the rubber entirely and blow its material out as dust. This occurred several times, until Messrs. Edwards and Worthington decided to wrap the "packer" with iron wire before inserting the same, which finally proved successful and the well was shut in. This is the well which gave a pressure of 800 pounds (the limit of the gauge) almost instantly, or within two or three seconds, according to Mr. Edwards. The well was completed on the 19th of August, 1893, and after supplying the towns of Fairmont and Grafton, 25 miles distant for four years, still showed a rock pressure at the well of 765 pounds, January 1, 1898, and of 550 pounds January 1, 1899. Its production through the open casing when first struck, must have been enormous, probably between 35 and 40 million cubic feet daily.

The greatest pressure recorded from this same sand was made in the Nineveh region of Greene county, Penna., where a gas well on the Michael Funk farm was shut in by Mr. John Worthington, and although of comparatively small volume, the *rock pressure* finally surpassed the limits of the gauge (1500 pounds to the square inch), and did not stop until it blew up class of pipe is supposed to be tested to 2,000 pounds before it leaves the factory.

It is quite probable that the total *rock pressure* in these deep sands (*Campbell's Run, Flat Run, 4th, 5th and 6th*) of West Virginia would exceed 1500 pounds to the square inch in the deepest portions of the field, if shut in and packed down to the top of each stratum in question.

A curious fact was discovered at the Alonzo Edwards well No. 1, near Wadestown, Monongalia county, West Va. This well was drilled by the Battelle Oil Company, and considerable gas was developed in the *Gantz Sand* horizon at 2770 feet, as well as in the *"Fifty-Foot"* Sand at 2840 feet, and a still larger flow was found in the *5th* or *McDonald Sand* at 3115 feet, the hole being completed at 3300 feet. The *Gantz* and *"Fifty-Foot"* sands constituted one solid, coarse, pebbly rock, and in order to save all of the gas flows, the well was packed in the upper portion of this pebbly stratum. From the great depth of the well, it was expected that the *rock pressure* would rise until it exceeded 1,500 pounds to the square inch, but when shut in the gauge which began to register rapidly at first, very soon slowed up, and finally stopped at only 650 pounds. As the pressure did not rise sufficiently rapid to correspond to the apparent volume of the gas when the gate valve was open, it was concluded that a large portion of the gas was being forced into the porous *Gantz* and *"Fifty-Foot"* beds, and *stored* therein, the 650 pounds representing the pressure necessary to store in the pores of that rock all the surplus gas produced from the three horizons at that pressure. This *storing* process could not of course go on indefinitely, since the new reservoir would require additional pressure to force the gas further and further back into the rock, and the conclusion was reached that in time the *rock pressure* of the well would show a large increase, and that the gas being thus stored up in natural reservoirs would be available for future consumption. This conclusion was subsequently verified. The well was shut in early in 1898, and not opened again (as there oil wells. The pressure, though not measured, proved so great that the two-inch pipe was blown up in several places, and it was found necessary to place a "reducing" arrangement upon the well.

Mr. Glen T. Braden, General Manager of the South Penn Oil Co., reports that he had the same experience with a well in Marion county, W. Va., similarly packed several hundred feet above the gas producing horizon, and that after the well had been shut in for 30 days, its pressure rose more rapidly and went to a higher point when opened and again closed in, thus demonstrating that the gas was being forced into porous beds and stored there in such a manner as to be available for future use. These facts should give a hint to the gas companies concerning a cheap method of *storing* gas wells not needed in the lines, viz., to connect the same with partially exhausted wells, and thus prevent too high pressures in the pipe lines, and at the same time preserve for useful work this surplus gas which would otherwise be wasted into the air from safety valves, etc.

The *rock pressures* in the *Big Injun Sand* are less than those in the *Gordon group,* since the top of the *Big Injun* lies 800-900 feet above the top of the *Gordon.*

In the Mount Morris region of Pennsylvania, and the adjoining district of Monongalia county, West Virginia, the pressure was about 550 pounds to the square inch soon after the field was opened in 1886, while at Blacksville, 8 miles west, where the same sand lies about 100 feet lower, the *rock pressure* in the *Big Injun* was 600 pounds when the first well was drilled. At Mannington the *Big Injun Sand* gave a total of 550 pounds at the Blackshere gas well, the first one opened to that sand, while the Snoderly gas well in the *Pottsville conglomerate* ("Salt Sand,") 400 feet higher up in the geological scale, stopped at 380 pounds. At Harrisville, Ritchie county, the *rock pressure* in the Big Injun sand was 680 pounds in the first well drilled by the Keystone Co., as reported by its president, Dr. D. H. Courtney, while still higher pressures are reported

Cairo, W. Va., informs me that when he first came to the Cairo region, ('96), the *rock pressure* in the *Salt Sand* gas wells was about 600 pounds to the square inch, and 900 pounds in the "*Big Injun*" sand below, thus greatly exceeding the highest pressures observed for the same strata in the northern portion of the state.

The *rock pressure* in the "Salt Sand" or Pottsville series seldom exceeds 400-500 pounds, since it comes 200 to 300 feet above the *Big Injun* horizon. Probably the largest gas well in the state at the present time is one owned by the Hope Natural Gas Co. on the Jacob McConkey farm, Harrison county, which, according to Mr. Glen T. Braden, shows a *rock pressure* of 985 pounds in the Gordon sand, and has a volume of 26,000,000 feet daily when flowing into the air. This well is shut in and has never been utilized. The greatest rock pressure now recorded anywhere in the state, according to Mr. Braden, is in Lewis county, where a pressure of 1125 pounds is shown by a well on the J. S. Norris farm.

In a later chapter of this volume it is hoped to present a few letters and statements from the superintendents of the several gas companies operating in West Virginia with reference to the rock pressure, and volume of some of the remarkable gas wells in different portions of the state.

The very high rock pressure recorded in Wetzel and Tyler counties in 1898 and 1899 is now a thing of the past, since so much gas has been wasted there through oil wells, and other escapes that the great gas companies, like the Philadelphia, Hope, and Carnegie, have found it necessary to install immense pumping stations in that region in order to force the gas through their lines to the principal points of consumption as Pittsburg, Cleveland, etc. When these wells had a high rock pressure, they would deliver in Cleveland 40 million feet of gas daily, through the 180 miles of 16-inch pipe line that connects the latter city with the West Virginia gas fields.

PENDLETON COUNTY WELL RECORDS.

Pendleton County Permit and Map Numbers.

nd-No.	*Farm Name and Well No.*	*Company.*	*District.*
	Harper, Mrs. Clara, No. 1	North Fork Oil & Gas	Union

Mrs. Clara Harper No. 1 Well.

ion District, Pendleton County, W. Va.
North Fork Oil & Gas Company.
nd-A on map. (Outside map border).
vation, 1870′ B.
hole.
ated 5.53 mi. S. of 38° 50′ and 1.06 mi. W. of 79° 25′—SW—Onego
uadrangle.
west side of North Fork of South Branch of Potomac River.
mi. N. of Riverton; 1.1 mi. S. E. of Mallon School.

	Top.	Bottom.	Thickness.	Elevation (top)
niferous Lime	178	200	22	+1692
kany Sand	220	235	15	+1650

arks: Well was shut down July 1, 1919. Total depth, 1850′?
Dip 70°± westward. Starts in Marcellus Black Shale.
Stratigraphic depth, 481′±.
Oriskany Sand crops 400′ east of well and Clinton ¼ mi. farther east.
Sands reported at 790-815′, 1190-1200′, 1290-1300′, 1507-1517′, and 1800-1850′.

Dr. J. H. C. Martens and are on file at the Survey's offices where they may be examined by any interested geologist or operator.

The following table summarizes the deep-well drilling in West Virginia up to May 1, 1943. It shows the number of gas, oil, and dry holes drilled, and the number of wells drilling, and total number, by counties:

Status of Deep-Well Drilling in West Virginia by Counties to May 1, 1943

County	Gas	Oil	Dry	Drilling	Total
Boone	31	0	10	1	42
Cabell	38	0	7	0	45
Calhoun	1	0	1	0	2
Doddridge	0	0	1	0	1
Fayette	0	0	1	0	1
Hampshire	0	0	3	0	3
Hancock	1	0	1	0	2
Harrison	1	0	3	0	4
Jackson	326	1	31	44	402
Kanawha	538	2	43	28	611
Lewis	1	0	1	0	2
Lincoln	21	0	5	5	31
Logan	2	0	1	0	3
McDowell	0	0	1	1	2
Marion	0	0	1	0	1
Marshall	0	0	3	0	3
Mason	4	0	7	0	11
Mingo	9	0	2	0	11
Monongalia	0	0	1	0	1
Pendleton	0	0	1	0	1
Pleasants	0	1	1	0	2
Putnam	24	0	5	8	37
Raleigh	0	0	1	1	2
Randolph	0	0	2	0	2
Ritchie	0	0	1	0	1
Roane	0	0	6	0	6
Tucker	0	0	1	1	2
Tyler	0	0	1	0	1
Wayne	70	1	13	1	85
Wirt	1	0	3	1	5
Wood	2	0	9	0	11
Wyoming	0	0	0	2	2